Comparative Evaluation Of Commercially Grown Lupin And Mung Sprouts

Sant B. Kaur

Edith Cowan University

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Comparative evaluation of commercially grown lupin and mung sprouts

By

Sant bir Kaur

A research project submitted in fulfilment of the requirements for the award of Master of Applied Science, in the Department of Consumer Science, Edith Cowan University, Western Australia

June 1994
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SUMMARY

More than one million tonnes of lupin seed are produced per annum in Western Australia. Lupin can be considered as an alternative to staple pulse food items such as soybeans, peas, chick peas and mung beans.

This research was designed to provide potential investors with objective scientifically obtained evidence of the feasibility, and marketing potential, of using lupin as a basis for the commercial development of value-added foods, in this case commercially grown lupin sprouts.

Sprouts were selected because sprouted lupins are comparable with mung bean sprouts, the market leader, as regards yield and consumer acceptance as a food ingredient. Moreover, there is evidence that Perth based manufacturers of mung bean sprouts experience problems with the supply and quality of the raw mung seeds.

The hypothesis which I sought to test was that lupin could be used for the commercial production of sprouts, either as a substitute for mung sprouts or as an additional sprout crop.

The commercial environment at JAS is described and analysed in comparison with Guidelines provided in the Camden Technical Manual. Lupin sprouts can be grown commercially with a few modifications in the procedures as used for the production of mung.

The programme of research was done in two major components. A series of preliminary small scale experiments was conducted involving temperature measurements, microbiological testing, physical observations and evaluation of the growing environment. Similar measurements and observations were done on full scale commercial sized batches. A survey was conducted to study the sprout usage by Caucasian and South East Asian consumers.

Major findings of the research showed that lupin sprouts have a better potential as a new or a complementary product rather than as a substitute to mung sprouts. It has potential in the domestic as well as the off-shore market as a value-added product. As a result of this research, lupin sprouts were introduced into 11 retail centres in the Perth metropolitan area. Lupin sprouts also have a cost advantage over mung primarily because of its lower seed price. Lupin offers an exciting new opportunity for the commercial producers of sprout crops.
DECLARATION

I certify that this research does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education and, that to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference has been made in the text.

Signature:

Date: 23 Jan. 1995
ACKNOWLEDGEMENTS

I express my sincere appreciation for the assistance rendered to me by the following persons and institutions, without whose help this thesis would not have been completed.

To my supervisors, Dr Francis Flanagan, Senior Lecturer, Department of Consumer Science, Edith Cowan University and Mr David Petterson, Senior Research Officer, Division of Animal Industries, Department of Agriculture, Western Australia. In addition to his formal assistance as my technical supervisor, Mr Petterson spent much time in correcting the thesis drafts and arranging for the final presentation of the thesis in an acceptable professional manner by Miss Shelly Ford of the Word Processing Centre of the Department of Agriculture.

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To the Grain Research and Development Corporation for their financial support for the research, without which the research programme could not have been started.

To all those individuals who participated in the sensory evaluation testing, for their time and courtesy in answering the consumer questionnaire.

To my husband, Mahesh Singh for his assistance with computer graphics and my children, daughter Jasmine and son, Angad for being so patient and supportive.
THESIS ARRANGEMENT

This thesis is presented in five main sections.

Section 1

The prefatorial pages: Title page, summary, preliminary pages, acknowledgements, thesis arrangement and technical information, contents, list of tables, list of figures.

Section 2

The introductory chapters, numbers 1 to 4. These are presented as:

Chapter 1. Introduction, which includes the hypothesis and statement of the problems, aims and significance of the work.

Chapter 2. Included in this chapter is the main body of the literature review and the classification of food legumes.

Chapter 3. Germination and sprouting; definitions and processes; nutritional benefits.

Chapter 4. Lupin and mung bean sprouts - comparisons; commercial sprout manufacture in Western Australia.

Section 3

The programme of research

Chapter 5. The factory environment, evaluation of the factory environment.

Chapter 6. Small scale production series of experiments; results; discussion; microbiological testing and methods. Full scale commercial production series of experiments initial trial; methods; results; conclusions.
Chapter 7. Cost analysis: lupin compared with mung.

Chapter 8. Consumer research, Asian and Caucasian food patterns; survey questionnaire; analysis and results; marketing and promotion of sprouts; discussion.

Section 4

Conclusions

Chapter 9. Conclusions; recommendations; limitations of the research.

Section 5

References and appendices
TECHNICAL INFORMATION

The following standards have been used in the preparation of this thesis.

**Spelling**


**Units of measurement**


Abbreviations, where used, adhere to these International Standards and have only been used when appropriate to the textual material and style.

**Style guides**

Several style guides have been used for reference purposes.


**Thesis design**

The textual printing design uses the standards for technical reports and manuscripts of the Word Processing Centre, Department of Agriculture, Western Australia. The headings and typefaces used were:

1. Chapter headings: 14 pt, Helvetica, bold, upper case, sanserif
2. Heading 1: 12 pt, Helvetica, bold, upper and lower case, sanserif
3. Heading 2: 12 pt, Times Roman, bold, upper and lower case, serif
4. Heading 3: 12 pt, Times Roman, italics, upper and lower case, serif
5. Heading 4: 12 pt, Times Roman, normal text, upper and lower case, serif
6. Text: 12 pt, Times Roman, normal text, upper and lower case, serif
7. Figures and table headings: 10 pt, Times Roman, bold, upper and lower case, serif

An Apple Macintosh computer, Quadra 605 using Microsoft Word 5.0 was used for final text preparation with a LaserWriter Pro 630 printer.

The colour photographs were reproduced using laser photocopying techniques.
CHAPTER 1

Introduction

*Lupinus angustifolius* is the principal species of lupin grown in Western Australia. Lupins are now approved throughout Australia as a base or ingredient in foods intended for human consumption. Lupin is a legume with a high seed protein content which is reported to have cholesterol lowering properties. More than one million tonnes of lupin seed are produced per annum in Western Australia. Lupin seed can be considered as an alternative to staple pulse food items such as soybeans, peas, chick peas and mung beans.

Various foods have been developed using lupin as a base or major ingredient. These include breads and cakes, biscuits, soups, pasta, spring rolls, stir-fries and pickles with the lupin in the form of flour, whole seeds, sprouts, fibre and splits. The results of sensory evaluations of a number of these lupin-based foods suggest that they are at least as acceptable in both sensory and attitudinal terms as similar products which contain traditional pulses.

Given the body of evidence which suggests that lupin is an acceptable food ingredient, there is little evidence that any of the research effort has led to the introduction of lupin-based value-added products in the market-place. It seems that there is considerable resistance to the commercial use of lupin which will have to be overcome if this potentially valuable primary product is to realize its market potential. At least part of this resistance seems to be related to the relatively high financial risks facing the down stream processor of any new product and an air of uncertainty about translating successful research to successful commercial manufacturing.
There seems to be a significant 'innovation gap' between the positive results of well-designed laboratory-based experiments and the adoption of commercial decisions necessary for the development of those products.

Hypothesis

The hypothesis which I sought to test was that lupin could be used for the commercial production of sprouts, either as a substitute for mung sprouts or as an additional sprout crop. The implication of this is that the production of lupin sprouts must have economic advantages over other seed sources for sprouts and be acceptable to consumers. A programme of research was constructed to test this hypothesis.

As a consequence, the main goals of this research were to demonstrate that lupin sprouts can be produced satisfactorily under normal commercial (factory) growing conditions and that a systematic, scientific approach to the use of lupin products for commercial development can assist in the introduction of new food products onto the market-place.

The problem

There is adequate evidence that a number of lupin-based value-added products can be produced which are acceptable to most consumers. It is also clear that few lupin-based products have actually reached the market-place. There seems to be a significant 'innovation gap' between the results of well-designed laboratory-based research studies and the implementation of commercial decisions necessary for the development of such products.

To bridge the 'innovation gap', it is necessary to demonstrate the potential benefits of these products to investors and down-stream processors of value-added foods so that there will be a reduction in the perceived financial risks involved in making those decisions.
This research was designed to provide potential investors with objective scientifically obtained evidence of the feasibility and marketing potential of using lupin seed as a basis for the commercial development of value-added foods. In this case, the value-added product chosen for evaluation was commercially grown lupin seed sprouts. Sprouts were selected because firstly, they are one of the simplest and more profitable ways of adding value and secondly, because there is evidence that sprouted lupins are comparable to mung bean sprouts, the market leader, as regards yield and consumer acceptance as a food ingredient.

There is evidence which suggests that Perth based manufacturers of mung bean sprouts experience problems with the supply and quality of the raw mung seeds.

While this research focuses specifically upon a comparison between the commercial uses of lupin and mung sprouts, the underlying purpose of this research, in addition to those already articulated, is to provide potential investors with information as to the use of lupin and other legumes. This information will provide a general strategy for the reduction of the perceived risks involved in product innovation in the food processing industry in Australia.

Aims

- To evaluate a manufacturing facility for the commercial production of mung sprouts.
- To determine the suitability of that facility for the commercial production of lupin sprouts.
- To identify the chemical, biological and environmental changes that take place during the commercial production of mung and lupin sprouts.
- To compare lupin and mung sprouts grown under identical commercial conditions with regards to:
  1. Physical growth characteristics (size, weight)
  2. Appearance and sensory attributes.
3. Commercial costs and benefits

4. Attitudes and behaviour of potential consumers.

Significance

It is essential that innovative and thoroughly researched techniques be used for the development of commercial food products. Unfortunately, this approach has not always received the attention warranted even though the approach could give the potential investor the type of information needed to make informed judgements as to whether they should invest in product development. Such information narrows the innovation gap and provides commercial data which is of critical importance and is necessary if the grain legumes industry is to gain financial returns from the introduction of new value-added products incorporating lupin onto the market-place. If successful, this research into product development will help to reduce the barriers to innovation so evident in parts of the food industry in Australia today.

Success in the area of lupin sprout production could lead to similar approaches being used to develop and evaluate other value-added lupin products grown under commercial conditions.
CHAPTER 2

Literature review

A brief review of the literature concerning the history of the development of mung and lupin and their use as a food ingredient for human use is now presented.

Mung

*Origin and geographic distribution, production and international trade*

*Vigna radiata,* commonly known as green gram, mung bean, moong or golden gram originated in India or the Indo-Burmese region (Maesen and Somaatmadja 1989, p. 71). The first record of the plant is contained in the medical writings of the Chinese Emperor Sheng-Nung, in 2383 BC and mung seems to have been exclusively grown for sprouting (Courter 1973, p. 49). The cultivation of mung has spread more recently to other continents. In most South East Asian countries, mung bean ranks among the three main grain legumes. The image of mung beans was associated, in some countries, as the ‘poor man’s meat’. That is why, despite being widely distributed, it never became a major crop outside Asia. Mung seeds are mainly used for sprouting in China and for dhal in India. Mung sprouts are a staple in Oriental diets. This has led to a rapid increase in domestic demand in most South East Asian countries and to high market prices. Moreover, there has been an increased awareness of the use of legumes and sprouts in diets. This has changed the image of mung to that of an economical and nutritionally valued source of food rather than ‘poor man’s meat’. There has been an increase in production of mung crops in the Asian region since 1980. In Indonesia, the area harvested doubled and domestic production tripled between 1975 and 1985. International trade is dominated by Thailand, which exports half of its production of 250,000 t/a mainly to Japan, Taiwan, Philippines, Malaysia and Singapore, and also to Europe and the
United States of America (Maesen and Somaatmadja 1989, p. 71 and Adsule, Kadam and Salunkhe 1984, p. 65).

Australian mung bean production is around 15,000 t/a (Pestna 1993, p. 249). In Australia, the major area of production of mung is in Queensland and northern New South Wales. Only a very small amount of mung is grown in the Northern Territory and in the Kimberley region of Western Australia (D. Petterson, personal communication, July 1993).

As mung is a short duration crop and has a wide adaptability, it is extensively grown on all types of soils and under varying climatic conditions. It can be grown all year round as a single crop or as an intercrop in double and/or multiple cropping systems. In some circumstances, mung may grow successfully in arid and semi-arid areas, where other crops usually fail. It is an excellent source of protein with high digestibility (Adsule, Kadam and Salunkhe 1984, p. 65).

**Uses**

Dried mung beans are processed and used in number of ways for human consumption. Common methods of processing include milling, sprouting, roasting, fermentation, cooking and frying. Mung beans are of versatile use and can be used as whole seeds, splits (dhal), flour or as an isolate (Salunkhe and Kadam 1989b, p. 72). Processed mung is often fed to babies, convalescents and the elderly or used when ending a long fasting period (Adsule, Kadam and Salunkhe 1984, p. 65). The crop residues are a useful fodder (Maesen and Somaatmadja 1989, p. 71).

Varieties of dishes such as soups, porridge, snacks, bread, noodles and even ice-cream can be prepared using mung as the base or as a major ingredient. Mung bean starch and protein can be separated by air blow drying. Mung bean starch is extensively used for making noodles. Mung bean protein is used to fortify cereal flours. The noodles are reported to have a better appearance and are more translucent. These noodles also have improved cooking quality and are easier to
pack when compared with traditional noodles (Wang and Hesseltine 1981 p. 71). The mung protein isolate is comparable to soybean protein isolate and could be successfully incorporated as nutritional and functional ingredients in many food products (Salunkhe and Kadam 1989b, p. 81).

Sprouted mung beans are most popular as a fresh vegetable in Chinese, Japanese and other Oriental cuisines. Sprouts can be frozen and canned. Among the legumes, mung beans are easiest to grow as sprouts (Maesen and Somaatmadja 1989b, p. 71). Datta and Manjrekar (1983, cited by Salunkhe and Kadam 1989b, p. 75) have suggested the preservation of mung sprouts by blanching in 10 per cent NaCl solution and dehydration at 55°C for 6 to 8 hours. The dried sprouts can be packed into polythene bags and stored until used and exhibit excellent reconstitution and keeping quality. Another experiment by Farhangi and Valadon (1983 p. 1251) on canned or bottled sprouts stored for six months at various temperatures suggests that there was browning of sprouts with time.

Biscuits and noodles made from germinated mung beans were found to be nutritionally superior to equivalent products made with wheat alone (Mabesa, Atutubo and Daquil cited by Salunkhe and Kadam 1989b, p. 79). Finney, Beguin and Hubbard (1982, p. 520) found that flours made from whole mung bean were unsuitable for straight dough breads because of undesirable 'beany' off flavours even at a low replacement level of 5 per cent. Dehulled mung produced excellent bread at 5 per cent and acceptable bread at 10 to 15 per cent substitution in bakers flour. Incorporation of mung sprouts at 5 to 10 per cent replacement level produced unacceptable bread flavours and structure.

In India, whole mung beans are normally used for preparing rice-mung weaning food. However, the high bulk density or high viscosity of weaning food based on cereal-legume blends limits the total intake by the child. Thus, emphasis is given to weaning foods with lower paste viscosity or high calorie density. Malleshi and Desikachar (1982, p. 193) conducted an experiment on the formulation of weaning...
food with refined ragi (cereal) and mung flour in a ratio of 70:30. They found that the hot paste viscosity of malted weaning food was much lower than that of several brands of weaning foods available in the market at that time.

Mung beans are very popular as a food for human consumption and are used extensively as sprouts, soups, bread and as an ingredient in traditional Eastern diets. New uses of mung are as a weaning food, baby food and the use of composite flours and isolates is being continuously explored.

Lupin

*Origin and geographic distribution, production and international trade*

Members of the *Lupinus* genus are known to many people as a green manure plant or garden flower. They are used in some agriculture systems in temperate environments. Lupins are native to the Mediterranean region, East Africa and the American continents. They are mostly cultivated on non alkaline soils where the average annual rainfall exceeds 350 mm. The lupin plant, like other legumes, has the ability to fix atmospheric nitrogen. It has a tap root which enables it to survive in deep, sandy, infertile soils. This is why lupin production has often been associated with such soils. However, lupins give their best production on well drained fertile sandy loams. Various species, including several bitter types, are now grown in many countries; Australia, Russia, Ukraine and Poland are the largest producers. Dr von Sengbusch started modern lupin breeding in Germany in the 1920s. He discovered several alkaloid-free sweet mutants of *L. luteus* and *L. angustifolius*. This pioneering work was later followed in Western Australia to develop 'sweet or low alkaloid varieties 'of the narrow-leaved lupin *L. angustifolius* (Nelson and Delane 1990, p. 4).

Dr J.S. Gladstones, developed cultivars of *L. angustifolius* from the semi-wild type species into true crop plants in less than 15 years (Nelson and Delane 1990, p. 5). Western Australia produced 77,000 tonnes of lupins in 1975. By 1992, growers harvested more than ten times this tonnage. The 1993 harvest was expected to
exceed one million tonnes. The Western Australian sweet lupin is domestically and internationally recognized as consistent for its quality and nutritional value. This fact is reflected by regular exports to Europe, Japan, Korea, Indonesia and other markets. Until 1990, the biggest problem facing marketers of lupin was an irregular supply. There had been some difficulty selling all the Western Australian lupin deliveries and some buyers had been unable to purchase their full requirements (Nelson and Delane 1990, p. 84). There is now a regular supply of high quality raw material which could support the food processing industry to produce a wide range of products (D. Petterson, personal communication. July 1993). Figure 1, shows major lupin growing areas in Western Australia.

![Major lupin growing areas in Western Australia.](image)

Figure 1. Major lupin growing areas in Western Australia. After Nelson P. and Delane R. Producing lupins in Western Australia (1990).

The lupins produced in Western Australia are still sold mainly for stock feed. In Western Australia today, about 200 tonnes of lupin hull (or bran) and 50 tonnes of
lupin kernels are used to produce lupin flour. Lupin flour is now available commercially on the domestic market (Nelson and Delane 1990, p. 83).

If lupins were to be used for other food markets, this could increase the financial return on lupins for Western Australian farmers (Yates 1991). The use of lupins in many different types of food is being continually explored. Research and sensory evaluation into the use of lupins in foods shows that lupins have great potential in both Oriental and Western foods (Kyle, Petterson and Evans 1991, p. 18).

Use of lupin in Western (Caucasian) food

Wheat flour is one of the major ingredients used in many Western foods. Research and sensory evaluation has been conducted into the possibility of incorporating some lupin flour into wheat flour based products such as bread, pasta, cakes and biscuits. Research indicates that 10 to 20 per cent of *L. albus* flour can be added to wheat flour without reduction in the quality of the bread in comparison with conventionally made wheat bread. Studies indicate that bread containing lupin flour stayed fresh longer than did conventional bread (Compos and Al-Das, cited by Hill 1986, p. 53). Petterson and Crosbie (1989) found that no more than 4 per cent *L. angustifolius* flour could be substituted for wheat flour into the 'high rise' bread without affecting the quality of the bread. Studies conducted by Lucisano and Pompei (1984) and Yates (1990) found that 30 per cent of *L. albus* flour incorporated into pasta was successful. Dagnia, (1990) found that a combination of 50 per cent *L. angustifolius* flour and 50 per cent rice flour produced good quality biscuits as regards taste and appearance. The addition of 20 per cent *L. mutabilis* flour to cake was also found to be successful (Ryss and Groot cited by Hill 1986, p. 53). *L. albus* seed has been used for centuries as a snack food by the Italians and is known as a lupini bean (Yates 1991, p. 36). Yates (1991), incorporated lupin kernels and sprouts in soup and found kernel soup was more acceptable than the soup containing soybeans. Results from sensory evaluation tests by Schweers (1989, p. 39) on lupin pops (made by soaking lupins in flavoured brine followed by
roasting showed they were acceptably chewy and nutty. From the research quoted, it can be shown that lupins can be successfully incorporated into Western food products in varying amounts.

*Use of lupin in Asian food*

Because of the similarities of lupins and soybeans, extensive food product development has been conducted using lupins as a substitute for soybean in Oriental foods (Yates 1991, p. 31). A blend of 30 per cent lupin seeds and 70 per cent soybean made an acceptable alternative to traditional soy sauce in regard to colour, taste and flavour. It was less acceptable than soy sauce, but it was acceptable overall (Hung, Papalois, Nithionandon, Jiang and Versteeg 1990 p. 33; Lee 1986, p. 70).

Agosin, Diaz, Aravena and Yanez (1989, p. 104) found that the sensory characteristics of deep-fried lupin showed potential. Lee (1986, p. 73) successfully produced a lupin milk from lupin protein concentrate. Miso is a paste-like product used as an ingredient in soups and sauces. Cunha and Beirao de Costa (1990, p. 32) found that lupin miso was similar in chemical properties to soybean miso, but with more acceptable sensory characteristics. The blending of 30 per cent of lupin milk with 70 per cent soy milk enabled the production of bean curd with no loss of yield or texture (Hung et al. 1990). A fried lupin/soy curd has favourable characteristics such as a golden colour, good texture and sponginess (Hung et al. 1990). Mok (1991, p. 97) indicated that a silken tofu containing lupin is not acceptable to Caucasian consumers in its present form. She further suggested that the incorporation of 20 per cent lupin milk may be a possible use in Silky Delight as a variant of tofu-fa. Lupin can be substituted for soybean in tempeh production (Fudiyansyah, Fairbrother and Petterson 1992, p. 64). The evidence suggests that lupin, at least in small amounts, can be successfully incorporated into a number of Asian food products.
Summary

It is clear that legumes, as a relatively low cost, but nutritious source of vegetable protein, have an important role to play in meeting the food needs of many consumers in both developed and less developed economies. While many legumes, such as soy and mung have already been accepted for many years as major source of vegetable protein in the market-place, this is not yet true for lupin seed. This may present a marketing opportunity for lupin growers and investors.

A considerable demand appears to exist for an increase in both the volume and the range of vegetable proteins now available to consumers. There is evidence also of the under-use of lupin as a value-added food in both domestic and off-shore consumer markets. These matters being so, one of the questions addressed in this research is whether there is further commercial scope for using lupin as an alternative to existing legumes or as an addition to the current range of legumes available for human consumption. As stated earlier, of those legumes now used as food products, the most likely commercial competitor for value-added lupin products appears to be mung beans.

Classification of food legumes

Several analytical techniques were used to compare lupin seed and mung seed to determine the extent to which they can be regarded as either commercial substitutes for each other, or whether they should be regarded as quite different products. The results of these analyses could have important implications for both the production and marketing of lupin products.

The analyses compare lupin and mung with regard to their botanical, chemical, nutritional and perceptual/sensory characteristics to provide entrepreneurs and downstream processors with better information on which to base their commercial decisions. These common methods of classification were used to provide the
necessary insights as to whether the two legumes could be expected to have a similar usage, such as for sprouts.

**Botanical classification of plants: Lupin and mung**

“The basic classification of plants which was most widely accepted in the latter part of the 19th century and the early part of the 20th century, used certain outstanding morphological features to group all plants into four divisions: the Thallophyta, Bryophyta, Pteridophyta and Spermatophyta” (Cronquist 1971, p. 81).

The Division Thallophyta, contains plants in which the conducting tissue is not differentiated into true roots, stem and leaves. Examples include algae, bacteria, fungi and lichens (Cronquist 1971, p. 81, Abercrombie, Hickman and Johnson 1961, p. 284). Plants belonging to the Division Bryophyta, including mosses, have stem and leaves, but are characterized by lack of vascular tissue and roots (Abercrombie et al. 1961, p. 43). The Division Pteridophyta, has plants with specialized conducting tissue which is differentiated into roots, stem and leaves (the vascular plants). These plants reproduce by spores (Cronquist 1971, n. 81).

The last of these four Divisions, Spermatophyta, contains the seed producing plants. These plants have highly developed stems, leaves, roots and vascular system (Abercrombie et al. 1961, p. 269). Examples of the Division Spermatophyta are most trees, shrubs, herbaceous plants and grasses. This Division is further divided into two major classes: gymnosperms (coniferous trees and others), and angiosperms (broad-leaved plants and crop plants) (Hughes and Metcalfe 1972, p. 113).

The latter is divided into the sub-classes: monocotyledons and dicotyledons (Langenheim and Thimann 1982, p. 226). Cotyledons form a part of the seed embryo. Their major function is to provide energy and nutrition to the seedling during germination (Abercrombie et al. 1961, p. 75). These subclasses are then divided into orders, families, tribes, genera, and species. For this research, further discussion focuses upon members of the family Fabaceae or Leguminoseae which are dicotyledenous angiosperms.
Fabaceae (Papillinoaceae, Leguminosae)

The Leguminosae (Fabaceae, the legume family) has more than 500 genera and perhaps 13,000 species widely distributed throughout the world. It is one of the three largest families of flowering plants (Langenheim and Thimann 1982, p. 226). "In the broad sense they may be included in the order Rosales, but some botanists establish a separate order (Fabales) for the legumes and recognize three families instead of only one" (Cronquist 1971, p. 689). Lupin and mung belong to the family Leguminosae (Fabaceae).

The legumes are second only to the grasses in their importance as crop and pasture plants. Beans and peas in the genera Phaseolus, Glycine, Vigna, Lens and others provide protein rich foods for humans in tropical and temperate regions throughout the world. *Glycine max* (soybean) and *Arachis hypogea* (peanut) are valuable oil and protein crops. In Australia, species of the genera *Phaseolus, Desmodium* and *Stylosanthes*, are sown in the tropics and subtropics and species of *Trifolium* (clovers), *Vicia* (vetches), *Lupinus* (lupins) and others are sown for livestock in the temperate areas. *Lupinus* species are also sown for food and/or feed and floral (ornamental) purposes (Jackson and Jacobs 1985, p. 146).

The legumes are divided into three subfamilies. Faboideae, Caesalpinioideae and Mimosoideae. Members of the Caesalpinioideae and Mimosoideae are predominantly tropical. Although members of the Faboideae subfamily are predominantly tropical, some occur in both tropical and temperate regions and others are temperate in distribution (Jackson and Jacobs 1985, p. 146). Lupin and mung are both members of the subfamily Faboideae. However, mung is mostly grown in tropic and temperate regions whereas lupin is mostly grown in more temperate areas.

An outline of this classification system using mung (*Vigna radiata*) and lupin (*Lupinus angustifolius*) as an example is shown in Figure 2.
Figure 2. Botanical classification of *Lupinus angustifolius* (lupin) and *Vigna radiata* (mung)
By their botanical classification, mung and lupin are both members of the same family, but this does not automatically mean that they are either alternatives or substitutes for each other in relation to their use as food ingredients.

**Classification of food (grain) legumes based on seed size**

One convenient way to classify legumes is according to seed size. Those legumes with small seeds are classed as grass legumes or seed legumes, while legumes with larger seeds are classified as food legumes. Grass legumes are those plants which are grown mainly as pasture for grazing animals, are cut and dried as hay, and have fruit consisting of grain-like seed. Examples of these are alfalfa and clover. Grain or food legumes are plants whose fruit is dried and used mainly for human consumption. Examples of these are chickpeas, lentils, mung, soybean, peas, pigeon peas and red kidney beans (D. Petterson, personal communication, July 1993). Note: In Australia, *Medicago sativa* when used as a fodder is called lucerne. In North America it is known as alfalfa. Sprouts from this species are often called alfalfa sprouts.

This system is not perfect because alfalfa and clover are grass legumes, but are still used for human consumption in the form of sprouts. While the size of mung is very much smaller than red kidney beans or broad beans, all are food legumes. Lupin is a food legume, but has mainly been grown for fodder purposes; this was perhaps because of the presence of anti-nutrients. To cope with the increasing food demands of the world, more seed legumes are being domesticated and plant breeders are trying to eliminate most of the anti-nutrients. Sweet lupin seed has a very low level of antinutritional factors and lupin derived products offer many exciting possibilities for human nutrition (D. Petterson, personal communication. July 1993).

**Classification of food (grain) legumes based on energy storage**

Another useful classification of legumes is on the basis of how energy is stored in the seed.
Kadam, Deshpande and Jambhale (1989) classified food legumes into two categories: firstly, those in which energy is stored as fat e.g. peanuts and soybeans. The fat content of peanuts and soybean is about 40 per cent and 20 per cent respectively. A second category of classification suggested by Kadam et al. (1989) which includes those legumes in which energy is stored as starch or gum (e.g. chickpeas, cluster beans and pigeon peas) (1989, p. 23). Lupin does not fit into either of the above categories. A summary of the chemical composition of the four main species of Lupinus is given in Table 1.

Table 1. Chemical composition of four main cultivated lupin species- per cent, as received

<table>
<thead>
<tr>
<th>Species</th>
<th>Crude protein (N x 6.25)</th>
<th>Ether extract</th>
<th>Crude fibre</th>
<th>Ash</th>
<th>N-free* extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. albus</td>
<td>36.7</td>
<td>11.5</td>
<td>9.8</td>
<td>3.4</td>
<td>37.8</td>
</tr>
<tr>
<td>L. angustifolius</td>
<td>31.1</td>
<td>6.0</td>
<td>14.7</td>
<td>3.5</td>
<td>43.1</td>
</tr>
<tr>
<td>L. luteus</td>
<td>41.8</td>
<td>5.4</td>
<td>15.8</td>
<td>4.1</td>
<td>35.0</td>
</tr>
<tr>
<td>L. mutabilis</td>
<td>42.6</td>
<td>18.7</td>
<td>7.3</td>
<td>3.7</td>
<td>27.3</td>
</tr>
</tbody>
</table>

* Calculated by difference.

(Source: Gross 1988, p. 52)

The fat content of different species of lupin vary. L. angustifolius has 5 per cent fat, whereas L. albus and L. mutabilis have 11 per cent to 19 per cent fat and could be considered as potential oil sources (Gross 1988). Other species have too little oil to be put in the oil-rich seed group.

All of the lupin species are very low in starch, hence they do not qualify for the second classification category as suggested by Kadam et al. 1989 (D. Petterson, personal communication, July 1993).

Many botanists and nutritionists do not agree with such a classification. They believe there is another category of legume seeds which have 3 per cent or less fat, but are high in protein and starch. Examples of this category are mung, peas and lentils (D. Petterson, personal communication, July 1993). Lupins are high in protein...
and have more than 3 per cent fat, but the fat content is not as high as that found in soybean and peanuts. Moreover, lupins have no starch. As such, lupins are not regarded as similar to mung.

There are marked differences in the protein, fat, carbohydrate and crude fibre contents of various species of lupins. The high protein, high fibre, low starch and low alkaloid content of *L. angustifolius* makes them unique and potentially an important legume for human consumption.

**Classification of food (grain) legumes based on sprouting characteristics**

Courter (1973) classified seeds on the basis of their usage as sprouts, which probably has no relationship to their botanical classification. In Courter's view, seeds from any one family would behave similarly when the sprouts are used in cooking. Thus, when a recipe calls for one specific sprout, it is possible in practice to substitute any member of its sprout family without having to alter the recipe in any way. However, the taste may vary even though the substitution will not drastically change the proportions of bulk or water content in the recipe (Courter 1973, p. 42). Using Courter's system of classification, the following classes are derived:

1. **The small seeds:** These include alfalfa, clover, millet, mustard, radish and sesame. They grow rapidly, and the first small leaves have a delicate taste. This means that they should be exposed to light before harvesting. These sprouts are mostly used raw and are excellent in sandwiches and salads. They sprout well in combination with others and with members of their own group.

2. **The grains:** This class includes barley, oats, rye and wheat. The grain sprouts tend to become sweeter as they lengthen. They are used in baking and for salads.

3. **The tender beans:** Include mung beans and green lentils which are most reliable and can be sprouted in combination (more than one type of seed grown together) or in large quantities for commercial purposes. Usually they are
grown in dark conditions. Mung beans are specially used in Oriental cuisines as a stir-fry ingredient or steamed if they are to be used in salads. They are also well liked in their raw state by Western users.

4. The tough beans: Includes black-eyed peas, kidney beans, Lima beans, navy beans and pinto beans. These beans usually must be steamed, boiled or cooked in some manner before eating. They do not sprout well in combination and must be rinsed and frequently culled to prevent spoilage. This shows that these seeds need extra care and attention to produce good quality sprouts.

5. The soy family: Soybeans, garden peas and garbanzo (chickpeas) are similar to the tough beans and require extra care in sprouting and cooking. They are the most nutritious of all sprouts. Consumers may consider it rewarding to master the techniques used to sprout this group of legumes.

6. The heavy hulls: The hulls of sprouts such as peanuts, almonds, buckwheat, pumpkin and squash must be removed before cooking or eating.

7. The mucilaginous seeds: The mucilaginous seeds become sticky when they are soaked in water. The normal method of sprouting is not suitable for this group. Seeds are sprinkled over water in a saucer and are allowed to stand for eight hours or overnight. The seeds will have absorbed the moisture and adhered to the bottom of the saucer by the morning. These seeds are rinsed by running water gently into the saucer and pouring it out. The mucilaginous seeds include chia, and cress.

Seeds and beans from different families can be sprouted simultaneously to produce interesting and tasty combinations which are cooked and eaten together. Members of tough beans, heavy hull and soy family however, do not sprout well in combination (Courter 1973, p. 42).

According to Courter's classification, mung beans are in a different class to lupin. Mung beans are classed as tender beans, lupins would probably be classified as a
member of the soy family. This means that lupin needs more care in sprouting and cooking than mung.

Comparison of mung and lupin: chemical composition

One of the major benefits legume seeds have is that they are regarded as nutritious; that is, they are low in cholesterol and fat, and high in protein and fibre. Legumes are versatile in use and can be used in salads, dips, soups, casseroles, as vegetables or as a meat substitute. Legumes are easy to store and keep well for at least a year and often much longer, and are available from most supermarkets and convenience stores.

Before any attempt is made to substitute lupin for mung in the form of sprouts, there is a need to compare the chemical composition of the two legumes. Legume seeds are generally characterized by a relatively high content of protein which varies between 17 per cent and 40 per cent, and a low oil content. The following Table 2 compares the major chemical constituents of lupin and mung.

Table 2. Chemical composition of lupin (Lupinus angustifolius) and mung (Vigna radiata) (g/100g dry matter)

<table>
<thead>
<tr>
<th></th>
<th>Lupin</th>
<th>Mung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>3.14</td>
<td>3.95</td>
</tr>
<tr>
<td>Crude fat</td>
<td>6.28</td>
<td>0.89</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>16.54</td>
<td>4.12</td>
</tr>
<tr>
<td>Protein</td>
<td>34.48</td>
<td>27.19</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.24</td>
<td>0.12</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.17</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.33</td>
<td>0.52</td>
</tr>
<tr>
<td>Gross energy (MJ/kg)</td>
<td>20.61</td>
<td>18.58</td>
</tr>
</tbody>
</table>

Adapted from Horton, Petterson, Mackintosh 1990 p. 14 and 32.

Protein

Legumes, as a source of vegetable protein, are nutritionally valuable and suitable for use in a wide variety of food dishes. While animal proteins are most regularly used
in Western countries, in Eastern Asian economies, in particular the Indian economy, the most widely used proteins are from vegetable sources. What makes legume protein important is that, on a per kilogram basis, legumes cost less than most animal and dairy protein sources (McKenzie 1992, p. 1).

Lupin seed contains more protein than do most pulses, including mung. Among commonly cultivated food legumes, mung bean protein is better balanced than the others in its amino acid composition although it is deficient in sulphur-containing amino acids and tryptophan (Nagpal and Bhatia cited by Salunkhe and Kadam 1989b, p. 68). Lupin protein is likewise deficient in sulphur containing amino acids followed by threonine (Cerletti, Fumagalli, and Venturin 1978, p. 1412). To be complete, lupin and mung beans, in common with all the legumes need to be combined with other foods such as cereals and seeds that are rich in sulphur containing amino acids. Salunkhe and Kadam (1989b) report that the addition of methionine is beneficial in improving the nutritional quality of mung bean protein. Dagnia (1990) found that supplementing a diet of lupin kernels or sprouts with 0.2 per cent DL-methionine improved its protein quality (1990 p. 60).

Globulins constitute about 80 per cent of the total storage protein in legume seeds (Salunkhe and Kadam 1989b, p. 67). In addition to the globulins, lupins have albumins (Cerletti, Duranti and Restani 1984, p. 472). In mung bean, a globulin-specific protease, vicilin-peptidohydrolase, has been reported to accumulate into protein bodies at the beginning of germination (Baumgartner and Chrispeels cited by Salunkhe 1989b, p. 68).

The nutritional value parameters of protein can be expressed as chemical score, digestibility coefficient, biological value, protein efficiency ratio and net protein utilisation (Salunkhe and Kadam 1989b, p. 68). The biological value of *L. angustifolius* is 53.5 (raw) and *L. albus* is 70.00 (raw) (Seveage *et al.* cited by Dagnia 1990, p. 16) while the biological value of mung bean is 70 and egg is 90 (Salunkhe and Kadam 1989b, p. 68). The higher value is an indicator of better
protein quality and so mung protein is rated as being of better quality than lupin. Boutrif (1991), while reviewing methods used for protein quality, found that; “After decades of use, it is now recognized that PER over-estimates the value of some animal protein for human growth while it under estimates the value of some vegetable proteins for that purpose”. The Codex Committee on Vegetable Proteins (CCVP) stated that there was a need for a suitable indicator to express protein quality. The Committee concluded that an amino acid scoring procedure, corrected for true digestibility of protein and/or bioavailability of limiting amino acids, would be the preferred approach to assessing protein quality of vegetable protein and other food products. Research on lupin and mung assessing these considerations would give a better approach towards protein quality (Boutrif 1991, p. 36).

**Fibre**

The seed coat (hull) of both lupin and mung contains most of their fibre content. The seed coat of mung is much thinner and softer than that of lupin. The testa of *Lupinus angustifolius* has 16.5 per cent of fibre compared with 4.12 per cent in mung (*Vigna radiata*). The thick seed coat requires longer treatments while cooking and produces a chewy taste if the lupins are incorporated into the diet and eaten with the seed coat.

The structural polysaccharides of legumes include two fibre components namely, cellulose and noncellulosic polymers. Crude fibre or cellulose is, however, essential but not metabolized in the human body. The soluble fibre in legumes is believed to help control cholesterol levels in blood (Rogers 1990, p. 301). The thick cell wall of lupin consists mostly of pectin-like material and small amounts of cellulose and hemicellulose. Evans, Cheung, and Cheetham, (1990) found that the serum cholesterol of rats decreased by 10 per cent when they were fed lupins kernels, flour and dietary fibre extract.
Although all legumes are regarded as good sources of crude fibre, it is the higher content of valuable dietary fibre which aids digestion and movement through the lower human digestive tract. Lupin is superior to mung in this regard.

*Lipids (fat)*

The lipid content of legume seed may vary depending upon the species and environmental factors operating during the growing season (Worthington *et al.* cited by Salunkhe and Kadam 1989b, p. 70). The crude fat content of both lupin and mung is relatively low at 6.2 per cent and 0.89 per cent respectively, compared with 18.7 per cent for soybean. Green gram (mung) lipids contain 72.8 per cent unsaturated and 27.7 per cent saturated fatty acids (Salunkhe and Kadam 1989b, p. 69). The fat content of *Lupinus angustifolius* comprises 75 per cent of unsaturated fatty acids. High proportions of these are linoleic and linolenic acids. The percentage of unsaturated fat in different varieties of lupin varies with light and temperature during the growing season (Crosbie, Petterson and Wilkinson 1988, p. 1).

Lupin and mung are equivalent on the basis of fat contents. As such, they could be used as a reasonably good alternative for meat for non-vegetarians who are concerned with the high fat content of meat in their diets.

*Anti-nutrients*

The major concern of any legume for human consumption is the possible presence of anti-nutrients. Anti-nutrients are ‘anti-predators’ and cause deterrent effects when consumed, such as bitter taste, gastric irritation, metabolic disturbances and neurological disturbances. Alkaloids, tannins and saponins are responsible for the bitter taste in raw seeds. Gastric irritation is caused by tannins, saponins and lectins. The tannins act as inhibitors as they decrease protein and carbohydrate digestibility and availability of vitamins and minerals. The presence of phytates reduce the availability of minerals. Oligosaccharides cause digestive discomfort because
raffinose, stachyose and verbasocse, which are low molecular weight alpha-galactosides are not broken down by normal enzymes. They pass into the hind gut where micro-organisms ferment the sugar to release carbon dioxide, hydrogen and methane. This can cause flatulence. A trypsin inhibitor (protease inhibitor) interferes with the action of the pancreatic enzyme, trypsin that digests polypeptides which contain arginine and lysine (Stare and McWilliams 1984, p. 108).

The anti-nutrient composition of lupin and mung

The anti-nutrient composition is compared with soybean as this species has the highest protein content of any legume. It also has a high anti-nutrient composition which is a matter of concern to researchers.

Petterson and Crosbie (1990), state that the content of anti-nutrients in lupins are lower than soybean.

Table 3. Anti-nutrient content of lupin, soybean and mung

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Lupin</th>
<th>Soybean</th>
<th>Mung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytate (%)</td>
<td>0.44</td>
<td>1.59</td>
<td>NA</td>
</tr>
<tr>
<td>Trypsin inhibitor (mg/g)</td>
<td>0.18</td>
<td>17.90</td>
<td>NA</td>
</tr>
<tr>
<td>Total phenolic %</td>
<td>0.29</td>
<td>0.57</td>
<td>NA</td>
</tr>
<tr>
<td>Lectins</td>
<td>-ve</td>
<td>+ve</td>
<td>NA</td>
</tr>
<tr>
<td>Oligosaccharides %</td>
<td>4.60</td>
<td>5.70</td>
<td>NA</td>
</tr>
</tbody>
</table>

NA - no data available.

Trypsin inhibitor activity has been reported to be low in green gram (mung) compared with other legumes (Jaya and Venkatraman 1980 cited by Salunkhe and Kadam 1989b, p. 71). Lupin seed contains about 0.18 mg of trypsin inhibitor which is low when compared with soybean (see Table 3).

All legumes are richer in phosphorus than most cereals, and phosphorus is mostly present as phytic acid. About 80 per cent of the total phosphorus may be as phytate (Salunkhe and Kadam 1989b, p. 71). The phytate content of lupin seed is about 0.44 per cent which is lower than the 1.59 per cent of soybean (Table 3). Rao et al.
(1983) reported total phosphorus content of 464 mg/100 g of green gram (mung) seeds which is almost equivalent to lupin, but is lower than soybean (cited by Salunkhe and Kadam 1989b, p. 71).

The flatus potential of green gram (mung) is attributed to the presence of starchyose and verbasocse (Aman 1979; Fleming 1981; Rao 1978 and Rao et al. 1973 cited by Salunkhe and Kadam 1989, p. 71). From Lupin angustifolius has been developed the modern sweet, low alkaloid cultivars which contain less than 200 mg/kg of alkaloids (D. Petterson personal communication. Nov 1992). Processing lupins may further decrease the level of alkaloids present. This would mean that lupin could be encouraged for human consumption in uses like those of any other legume after germinating or cooking.

Germination, fermentation, soaking and cooking considerably reduce the amounts of oligosaccharides present (Salunkhe and Kadam 1989b, p. 71). About 70 to 100 per cent of these oligosaccharides can be eliminated during germination (Rao et al., Gupta et al. cited by Salunkhe and Kadam 1989b, p. 72, Dagnia 1990, p. 37).

In summary, lupin and mung have favourable nutritional properties being high in protein and low in fat. Lupin also has a higher fibre content than mung. However, lupin does contain more anti-nutrients. Germination is believed to reduce the effect of anti-nutrients and increase the nutritional quality of the seeds. This factor is discussed later.

Summary of the comparison between lupin and mung

The literature shows that, while there are similarities between lupin and mung, they are not identical.

Mung has been widely consumed by humans as an important dietary component for several thousand years, whereas lupin was virtually rediscovered and used more recently for that purpose. Mung had been grown in the past mainly for human consumption, whereas lupin was grown almost entirely as a subsistence crop (a crop
grown under conditions where it is mainly consumed by the family) or as an animal fodder. Mung has been used as source of protein by many cultures to supplement their basic diets of rice, maize or other cereals, while lupin was used only as a substitution food when other crops had failed or as a snack (Jackson and Jacobs 1985, p. 150; Lee 1986, p. 64).

Figure 2 shows the botanical relation between mung and lupin. Mung and lupin are members of the same family, the Leguminoseae (Fabaceae). Mung belongs to the tribe Phaseoleae of which 90 per cent of its species are tropical and is grown as a pulse crop. Lupin belongs to tribe Loteae and is often grown on poorly drained acidic soils and swampy land (Jackson and Jacobs 1985, p. 150).

The classificatory system based on the seed size is arbitrary and does not provide a strong scientific basis for comparison. Courter (1973) has identified a relationship between the size of sprout produced and texture of sprout, to the size of seed selected. Rule of thumb for beans is that the larger the bean, the shorter would be the sprout. Large sized seeds produce sprouts which tend to be tougher than smaller seeds which produce tender sprouts (Courter 1973, p. 9). Since lupin seed is larger than mung seed, different characteristics of sprouts should be expected. It should have a tougher eating texture than mung. By this criterion, lupin and mung can not be regarded as direct substitutes for each other.

Courter’s classification on the sprout usage means that mung beans are different from lupin seed. Mung beans are classified as tender beans. Lupins would probably be classified as a member of soy family. This means that lupin should need more care in sprouting, handling and cooking than mung.

Lupin seed contains more protein than do most pulses, including mung. Among commonly cultivated food legumes, mung bean proteins are better balanced in amino acid composition. Mung is high in protein, low in fibre, low in starch and contains no alkaloids, whereas lupins are high in protein, high in fibre, low in starch and low in alkaloids. The composition of lupin makes them unique and an important legume.
for human consumption. The evidence indicates that mung and lupin are not direct substitutes for each other.

It seems that all legumes can be used interchangeably in food preparation to some extent, but each of these have unique characteristics. Although lupin and mung can be substituted for one another, they are likely to possess different food properties. In areas where people suffer from protein malnutrition, lupins, as an addition to existing legumes, would be beneficial as an effective and inexpensive way of providing protein. Substituting lupin for mung may reduce the pressure on existing resources. There could be a variety of different uses of mung where lupin could be tried as an alternative, though for this research, only the usage of mung and lupin for sprouting was studied.
CHAPTER 3

Germination and sprouting

Definitions

The terms germination and sprouting may be interpreted in different ways by botanists and nutritionists. As such, an understanding of these terms is necessary.

Botanists and agriculturists define germination as "the appearance of the radical (first root of the embryo) outside the seed coat". In some plant species, the seed coat splits first to reveal the radical. In these cases, the definition is modified to the "radical is required to show positive geotropism (i.e. bend towards the earth)" (Jackson and Jacobs 1985, p. 51).

The definition of germination, used in some agricultural legislation, is usually further qualified to include a measure of 'quality' of germination. This is to ensure that the seeds are germinating 'normally' and are likely to proceed through to the later stages of establishment to produce healthy plants (Jackson and Jacobs 1985, p. 51).

A seed might remain in the soil for months and germinate only when favourable conditions occur in the environment. However, seeds can be made to germinate artificially by creating favourable conditions in the laboratory, factory or home. This is the basis for sprouting seeds for human use.

Sprouting

Sprouting is an extension of the germination process. Botanists and agriculturists often refer to sprouting as "unwanted germination of seeds occurring in storage bags or containers because of poor storage conditions" (D. Petterson, personal communication, June 1993).

The term sprouting is frequently applied by nutritionists and health food proponents to mean the continuation of germination for 3 to 5 days under controlled conditions,
with an intermittent supply of water, during which seeds grow on their own internal reserves. Such sprouting is for the purpose of human consumption. Nutritionists advocate that sprouting is "an easy process to improve the nutritional quality of dried seeds". The centuries old practice of sprouting mung beans and soybeans is now being used for many other seeds as a means to improve nutritional worth (Hamilton and Vanderstoep 1979, p. 443).

An examination of the types of changes that occur during the germination process, and the benefits which these changes may have on the suitability of the sprouts as a food for human consumption, will now be discussed before the relative merits of mung and lupin sprouts are considered.

The process of germination

Jackson and Jacobs (1985, p. 51) state that the processes involved in germination can be separated into physical and biological changes. The latter can be further divided into biochemical and morphological changes.

(i) Physical changes

In the presence of water, oxygen and other favourable environmental conditions for germination, the first physical change that occurs in the seed is an uptake of water by the seed (imbibition). This change is reversible for a time and hence, for satisfactory germination, the favourable conditions should be extended for a certain period (Jackson and Jacobs 1985, p. 51). In the process of sprouting, the uptake of water can be accelerated by regularly providing a supply of fresh water.

(ii) Biochemical changes

Biological processes are dependent on the viability of the seed and are irreversible. The first observable metabolic change occurs well before germination is observed, with an increase in respiration rate (Jackson and Jacobs 1985, p. 51). Dry seeds have
a slow rate of respiration because of their low moisture content (only 5 to 10 per cent water). The rate of respiration begins to increase rapidly when the seeds are placed in water (Mayer and Poljakoff-Mayber 1963, p. 101).

The increased rate of respiration is caused by:

(a) an increase in the consumption of stored energy;
(b) an increase in hydrolysis;
(c) a change in enzyme concentrations; and
(d) an increase in vascular movement of sugars, (Jackson and Jacobs 1985, p. 51).

The increase in consumption of stored energy is because of a breakdown of the reserve material, starch or other complex carbohydrates, in the seed which is initiated by hydration of seed protein (Mayer and Poljakoff-Mayber 1963, p. 101).

These biochemical changes are interrelated with morphological changes such as an increase in cell elongation and cell division in the embryo (Jackson and Jacobs 1985, p. 51). The broken down reserves in the seed are transported from one part of the seed to another, for example, from the endosperm to the embryo or from the cotyledons to the growing parts. New products are synthesized from these metabolites (Mayer and Poljakoff-Mayber 1963, p. 111).

At the onset of germination, there is an initial loss in dry weight caused by the oxidation of substances and from the leakage of material from the seed. The dry weight begins to increase once the root emerges and begins to take up minerals. The cotyledons, if exposed to light, start to photosynthesize. The size of the cotyledons decreases as the hypocotyl and radical emerge (Mayer and Poljakoff-Mayber 1963, p. 111).

Nutrients, such as soluble sugars, insoluble polysaccharides, soluble and protein nitrogen and pentose nucleic acid phosphorus, move out of the cotyledons to the growing parts of the embryo. Large amounts of soluble sugars in the hypocotyl are a
result of transportation from the cotyledons and the breakdown of reserve carbohydrates, oligosaccharides and starch. Soluble nitrogen disperses from the cotyledons and appears in larger amounts in the radical than in the hypocotyl (Mayer and Poljakoff-Mayber 1963, p. 111).

(iii) Morphological changes

Following germination, the growth of the seedling can follow one or two different patterns. In the pea, the shoot (or epicotyl “above the cotyledons”) grows out directly from the cotyledons which stay below ground (or hypogaeal “below ground”). More commonly, legumes follow the dicotyledonous pattern of growth. The tissue between and below the cotyledons elongates into a long stem, (the hypocotyl “below the cotyledons”) following emergence of the radical. The hypocotyl arches upward and becomes the first part of the bean seedling to appear above the ground. As the hypocotyl continues to grow, it pulls the cotyledons upward into the air. The true epicotyl then develops from the node that bears the cotyledons. This pattern of growth is more widespread and is known as epigeal (“above ground”) Langenheim and Thimann 1982, p. 413).

The cotyledons move apart and the seed coat is shed. The cotyledons steadily decrease in size as their supply of stored nutrient is diminished and eventually becomes exhausted. Cotyledons often disappear completely when chloroplasts become fully established in developing stem and leaves (Langenheim et al. 1982, p. 413, Weisz and Keogh 1977, p. 71).
External factors influencing the germination/sprouting process

Apart from genetics and hereditary factors, such as dormancy and inhibition, many external factors influence germination. A seed can germinate only if it is in a favourable environment. The required conditions are water, an adequate temperature, a suitable composition of gases in the atmosphere and adequate light for certain seeds (Mayer and Poljakoff-Mayber 1963, p. 37; Jackson and Jacobs 1985, p. 52).

These factors are now discussed. These external factors need to be combined and manipulated when creating growing conditions favourable for effective sprouting.
An adequate supply of water is necessary before germination can take place. The first physical change involves the uptake of water by the seed. Factors contributing to the imbibition are: the composition of the seed, the permeability of water in liquid or gaseous form in the environment, and the amount and duration of access to water (Mayer and Poljakoff-Mayber 1963, p. 37).

Imbibition is a physical process not related to viability of the seed. During imbibition, molecules of water enter the seed by occupying the free capillary spaces resulting in a swelling of the seed. This swelling causes considerable pressure, called *imbibition pressure*. Increased imbibition pressure in the seed leads to the breaking of the seed coat (Mayer and Poljakoff-Mayber 1963, p. 38). More pressure is required for thicker seed coats. Mung has a thinner seed coat than lupin and the mung seed coat ruptures earlier than that of lupin when soaked in water for the same length of time. As the thick cell wall of lupin takes longer to rupture, this could mean that lupin needs a different watering regime to mung during commercial sprouting.

The swelling of seeds partially reflects the storage material present in the seed. Protein is the chief component which imbibes water. The mucilage of various kinds, part of the cellulose and the pectic substances, also contribute to swelling. Even if large amounts of starch are present in the seed, it does not contribute to swelling. Starches only swell at a very acid pH or after treatment with high temperatures (Mayer and Poljakoff-Mayber 1963, p. 39).

The permeability of the seed coat or testa is a significant factor in the imbibition process. Because entry of water is determined by the permeability of the seed coat the germination process will not start if the seed is surrounded by an impermeable coat (hard-seededness) even if all the otherwise favourable conditions are present. Legume seeds frequently have an impermeable coat. The seed coat is usually a multi-layered membrane and contains a number of layers of cells. The
impermeability of the seed coat, or its selective permeability, is usually the cause of dormancy. However, various external factors can cause changes in permeability of the seed coat. Permeability is usually greater near the micropylar end of the seed where the coat is thinner than the rest of the seed coat (Mayer and Poljakoff-Mayber 1963, p. 42-43).

The duration of the soaking period is critical as the uptake of water is reversible. The optimal duration of the wet period depends upon the species and other factors influencing germination. The amount of water available for germination has a less detrimental effect than the actual duration of availability of water (Mayer and Poljakoff-Mayber 1963, p. 52). This explains why the frequency of watering is important during sprouting. If the time gap between watering is too great, the developing sprouts can dry and wilt.

(b) Oxygen

Germination is a process of living cells which requires an expenditure of energy. This is a process of oxidation which may occur in the presence of gaseous oxygen and helps living cells to obtain the required energy. Respiration involves an exchange of gases, an uptake of oxygen and output of carbon dioxide. Seed germination is affected by the composition of the ambient atmosphere. Most seeds will germinate in air, at 20 per cent oxygen level and 0.03 per cent carbon dioxide. Increases in the amount of organic matter and moisture in the soil will tend to decrease the oxygen level in the soil (Mayer and Poljakoff-Mayber 1963, p. 43; Jackson and Jacobs 1985, p. 52).

(c) Temperature

Different seeds have different optimal temperature ranges for germination (Mayer and Poljakoff-Mayber 1963, p. 43). The observed effect of temperature reflects the overall resultant effect (Mayer and Poljakoff-Mayber 1963, p. 48). The change in temperature affects both the rate and the level of germination. The 'limits for
germination' can be quite different from the 'optimal temperature for germination' within a species or cultivar (Jackson and Jacobs 1985, p. 52). Optimal temperature is defined as the range of temperature within which a certain seed germinates, but below and above which germination is delayed, but not prevented. Optimal temperature is defined by Jackson and Jacobs as 'that at which the highest percentage of germination is attained in the shortest time' (1985, p. 46).

The source of seeds, genetic differences within a given species and varietal differences, as well as the age of the seeds can affect the temperature at which different seeds germinate and the range within which they germinate (Jackson and Jacobs 1985, p. 52).

Cohen (1958) (cited by Mayer and Poljakoff-Mayber 1963, p. 48) studied the effect of alternating temperatures on germination of lettuce seeds by measuring the actual temperature reached by the seeds. He suggested that neither the rate nor the duration of temperature change is critical in determining germination. The critical determining factor is the actual change of temperature of the seeds themselves. The result of temperature changes takes place in a macro-molecular structure in the seed which, in its original form, prevents germination in some way (Mayer and Poljakoff-Mayber 1963, p. 48).


Under natural conditions, seeds are subjected to diurnal temperatures, relative humidity and light patterns. It may be difficult to relate figures for optimum temperature of germination under laboratory conditions to those recorded under field conditions (Jackson and Jacobs 1985, p. 52). While sprouting seeds for the purpose
of eating, all the conditions are manipulated to achieve the highest germination rate in the minimum possible time.

The sprouting process, quantities and benefits

There are three basic factors that control the sprouting of the seed: the quantity of moisture available, the ambient temperature and the circulation of air. During the process of germination, chemical changes begin to take place; carbon dioxide and other gases and heat are released. These gases and residues create wastes which will accumulate if not dispersed. One of the most important steps in the sprouting process is to remove the wastes by rinsing the sprouts with fresh water or they will rot. While sprouts demand a constant supply of water, they cannot be left standing in even small amounts of water as they will quickly decay. Sprouts grow fastest in warm temperatures, free from draughts and away from direct heat. There should always be about one-third of the sprouter (equipment for growing sprouts at home) left empty for air circulation. Sprouts greatly expand both in size and volume as they grow.

The basic rules of sprouting are:

1. keep the sprouts moist, but never wet;
2. keep in a warm place while they are growing;
3. rinse them as often as possible.

The container used should be large enough so that the sprouts have room to breath and are not crammed. If the seeds do not sprout and there is a foul odour, this is a strong indication of crop failure. The problem of sprout crop failure is more common with larger beans such as soy, gerbanzo, kidney and pinto beans (Courter 1973, p. 37).
Courter suggests that sprouting can be done successfully in small quantities at home and also in larger quantities in a commercial environment for the purpose of selling and profit.

Sprouting at home

Several methods are suggested for sprouting at home such as the jar method, sprout bags, trays and/or automatic sprouters. Whatever method(s) is selected the basic steps remain the same, from the initial soaking and draining of the seeds through rinsing and care of growing sprouts, to their eventual harvest (Wigmore 1986, p. 43).

The jar and bag methods are cumbersome and time consuming, but there is negligible equipment cost. Automatic sprouters are expensive, but are convenient, simple to use and a reliable method for producing a consistent supply of good quality sprouts. Automatic sprouters look like a miniature chest of drawers, with 2 to 10 plastic or stainless steel drawers. Each drawer is actually a tray set at an angle for proper drainage. A series of fine misters are suspended from pipes above each drawer. Usually, the top drawer is covered with plastic, allowing light to reach the sprouts growing in it. Sprouts which do not require light, such as bean and grain sprouts, are grown in the lower drawers which remain dark. To use the sprouter, it is connected to water and power as directed in the manufacturer's instructions, an appropriate quantity of seeds are spread evenly on the tray and the unit is turned on. The sprouts are misted with water every few hours and the excess water is drained away. An optional 'grow light' bulb can be placed over a top tray for greening the sprouts more quickly (Wigmore 1986, p. 48-49).

The basic sprouting system requires a receptacle large enough to hold the finished sprouts, but this container must not be transparent. Wooden or metallic containers are preferred. Wide diameter containers are better than those which are tall, narrow or small mouthed, particularly when sprouting large quantities. To facilitate an even circulation of moisture and air, it is better to sprout in as few layers as possible. If
too large a quantity of seeds are used at one time, it can result in spoilage of the lower layers. The remaining items of equipment required are measuring cups, paper towels or pieces of cheese cloth, nylon mesh screening or any other non toxic material that will allow air to circulate and a large wire mesh strainer (Courter 1973, p. 21-23; Wigmore 1986, p. 43).

Sprouting large quantities

In China, many restaurants prefer to use in-house facilities to grow fresh bean sprouts. Alternatively, those without such a facility can buy from co-operatives who, in turn, have a number of small scale growers usually operating from home. In both instances, the average production unit is about 20 to 40 kg (W. Ming, personal communication 1993). The usual manufacturing process used in China is as below.

1. Quarter fill a large 64 litre crock or plastic garbage bin with beans.
2. Fill the crock to the brim with warm (26°C) water and let it stand overnight.
3. Drain. Cover with a wet tea towel and a tight lid.
4. Flush with water and drain two to three times daily. Moisten the towel each time. Some manufacturers do not fill the crock each time, but gently stir the beans. This changes their position in the crock. Moisten the tea towel often and rinse with water only if the beans seem to be drying out. This process is repeated daily and sprouts are ready to eat within 4 to 5 days (Courter 1973, p. 35).

Mung beans sprout best in large quantity lots and have a relatively high rate of success. The beans must be of the highest quality and of the previous year's crop. Experts can also sprout soybeans successfully in quantity (Courter 1973, p. 35).

The apparatus used for sprouting in larger quantities at home, may be improvised from clam pots, beer kegs and other containers with bottom spigots to facilitate draining. The equipment can be placed in a shower recess during the sprouting.
The shower spray provides the water needed during the sprouting process. The spray provides the water source for rinsing. With the spigot turned on, the water escapes directly into the shower drain (Courter 1973, p. 35).

In Western Australia, most sprouts are grown in large quantities in commercial manufacturing factories, rather than as a cottage industry. Such factories use sophisticated and mechanized equipment. The average production run of most plants is between 5 to 6 tonnes at a time depending on the facilities installed. The equipment used comprises growing chambers, an automated watering system, washing system and conveyors. The requirement for such equipment to grow mung bean sprouts is described in Technical Manual No. 25, September 1989 published by The Campden Food and Drink Research Association (UK). However, there is little literature available relating to detailed equipment specifications. The existing manufacturing practices of a leading sprout manufacturer is discussed later.

Seeds suitable for sprouting

Sprouts seems to have an almost universal appeal. There are so many varieties, each with its own texture and taste, that there will be at least one sprout to please everyone (Courter 1973, p. 14).

Some authorities contend that virtually 99 per cent of all vegetation is edible in the sprout stage, but some of the sprouts such as potato and tomato, are poisonous if eaten in quantity. The most common beans, seeds and grains for sprouting are alfalfa, lentil, mung, rye, soy (yellow) and wheat. Other popular species include almonds, buckwheat, chia, red clover, corn (yellow Texas), fenugreek, flax, garbanzos (chick-peas), millet, black mustard, unhulled oats, garden peas, unhulled pumpkin, black and red radish, rice, unhulled sesame, squash, sunflower (hulled and dehulled) and turnip. Health food workers report success in sprouting anise, asparagus, basil, barley, beets, caraway, carrots, celery, chives, cress, dill, eggplant,
faba beans, kale, kidney beans, lettuce, Lima beans, marjoram, onion, parsley, peanuts, black eyed peas, pinto beans, pumpkin, sage, spinach, Swiss chard and thyme (Courter 1973, p. 38 and 39).

While there is a wide variety of seeds and grain which will sprout successfully, it is important to find the right type for the purpose of sprouting. Seed-quality beans are generally recommended for sprouting as compared with food-quality. Seed quality means that seeds are meant to be grown and will successfully sprout. They are generally higher priced than food quality products. Seed quality products which are designed for use by farmers, have often been treated with chemicals to retard spoilage and combat pests. If these are to be used for sprouting, then extra care must be taken to wash them carefully before soaking. Food quality seeds are meant primarily for cooking in their dry, unsprouted state. They are of lesser grade and have a lower germination rate. Food quality seeds are generally free from toxic chemicals, but they may have been sprayed with preservatives to increase shelf life. This tends to interfere with initial sprouting and a low germination rate is often a feature with these quality seeds. Several rinsings before soaking could make these seeds sprout (Courter 1973, p. 37).

Uniformity of shape, size and colour of seeds tends to produce better quality of sprouts. Broken, chipped or otherwise damaged seeds may lead to problems with rot or may never sprout. A handful of bad seeds can often spoil the whole crop of sprouting plants (Wigmore 1986, p. 37). In Western Australia, it is difficult to obtain mung seeds of reliable quality which affects the quality of sprouts produced. However, lupin, because of being locally grown in Western Australia, can be graded to obtain uniform size at a reasonable price. The process of grading also removes broken, chipped or otherwise damaged seeds, thus ensuring a better quality sprouting seed.
Benefits of sprouting

There are a number of benefits to be derived from sprouting of raw seeds. These include improved financial returns and nutritional value and improvements in eating quantity.

Adding value

'Pound for pound (kilogram for kilogram) sprouts are perhaps the most nutritious food there is per dollar value' (Wigmore 1986, p. 23). Breaky (cited by Wigmore 1986, p. 23) assessed 30 different kinds of seeds as regards costs, weight and yields. He found that almonds sprouts costs the most at 26 cents per serving (1/2 cup size) followed by sunflower seeds at 14.5 cents per serving. The popular product alfalfa costs only 66 cents per kilo while its weight from seed to sprout increased over 66 per cent and volume increased by 2900 per cent. In the Breaky study, one unit of alfalfa seeds produced nearly seven times its weight as sprouts. On average, it costs a little over 20 cents per kilogram to grow these sprouts at home. Mung or Chinese bean sprouts cost 28 cents per 100 g and increased in volume more than ten times.

Several studies into the use of lupin for sprouting have been completed, El-Habbal and Attia (1987), Dagnia (1990) and Yates (1991). Boundy (cited in Yu, Kyle, Hung and Zeckler 1985, p. 177) suggests that 'there may be potential for the use of lupin for producing bean sprouts'. Yu et al. (1985, p. 177) sprouted two lupin species (L. angustifolius and L. albus) for five days and compared these to mung and soy sprouts grown under identical laboratory conditions. Sprouting lupin seed for 5 to 6 days also resulted in an increase in nutritive value (El-Habbal and Attia 1987, p. 957). A summary of the results of Yu et al. appear in Table 4.
Table 4. Analysis of seeds and sprouts

<table>
<thead>
<tr>
<th>Seed</th>
<th>(w/w) water</th>
<th>(w/w) lipid</th>
<th>Mean sprout length (mm)</th>
<th>Weight increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed</td>
<td>Sprouts</td>
<td>Seed</td>
<td>Hypocotyl</td>
</tr>
<tr>
<td>Lupin</td>
<td>1</td>
<td>92</td>
<td>4.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Soya</td>
<td>6</td>
<td>82</td>
<td>21.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Mung</td>
<td>12</td>
<td>92</td>
<td>2.4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Source: Yu et al. 1985, p. 177.

According to these results, lupin sprouts are longer than both soy and mung sprouts. The weight data show the amount of water absorbed during sprouting. The 7.5 fold increase of the lupin sprout is much greater than that for either soy or mung sprout, and is considered 'an excellent return' and economically desirable (Yu et al. 1985, p. 177). There will be a real advantage for sprout growers if they could use existing facilities for the growing of commercial size batches of mung for the growing of lupin sprouts.

Nutritional benefits

Germination leads to considerable changes in chemical composition. When a seed is germinating, a number of biochemical reactions occur. Certain materials are broken down (catabolism), others are transported from the cotyledons to the growing part, and new materials are synthesized (anabolism) from the broken down product (Yates, 1991, p. 18)

Much research has been done on the effects of germination on the chemical and nutritional value of legumes. A summary of some of those research results relating to lupin and mung is now considered. Literature reports on the effect of germination of lupin seed are derived from Lee (1986), Yu, Kyle, Hung and Zeckler (1985), El-Habbal and Attia (1987), Dagnia (1990) and Yates (1991). The research on mung is from Sattar, Durrani, Mahmood, Ahmad and Khan (1989) and Ganesh Kumar, Ventkataraman, Jaya and Krishnamurthy (1978).
The effect of germination on the nutrient content, minerals and anti-nutrients is summarized in Table 5.

Table 5. Summary of the effect of germination on the nutrient content and anti-nutrients in mung and lupin seeds

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Lupin</th>
<th>Mung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>+4</td>
<td>+5</td>
</tr>
<tr>
<td>Amino acid</td>
<td>-4</td>
<td>+2</td>
</tr>
<tr>
<td>Lipids</td>
<td>+4</td>
<td>-1</td>
</tr>
<tr>
<td>Vitamin 'C'</td>
<td></td>
<td>+2</td>
</tr>
<tr>
<td>Niacin</td>
<td>+3</td>
<td>+2</td>
</tr>
<tr>
<td>Thiamine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anti-nutrients</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Trypsin inhibitor</td>
<td>-5</td>
<td>-2</td>
</tr>
<tr>
<td>Phytic acid</td>
<td>-4</td>
<td>-5</td>
</tr>
<tr>
<td>Oligo saccharides</td>
<td>-4</td>
<td>-5</td>
</tr>
<tr>
<td>Alkaloids</td>
<td>-4</td>
<td>-5</td>
</tr>
</tbody>
</table>

+ Increase.
- Decrease.

Note: The numbers indicated in this table correspond to the following references:

References: The numbers in the table correspond to the references e.g. (1) El-Habbal and Attia (1987) found lipid content of lupin decreased when germinated.


Dagnia (1990) and Yates (1991) compared the chemical composition of the kernel of the seed of lupin with that of a sprout after six days germination. The results showed that, during germination, there is increase in moisture, protein, sodium and calcium and decrease in fat and the anti-nutrients alkaloids, oligosaccharides and phytate.

Protein

There is some evidence to suggest that the crude protein content of legumes increases following germination. However, it may not be a real increase. The increase may
occur as a result of losses of other soluble components or from metabolic process, rather than from a real gain in crude protein content. Dagnia (1990, p. 38) found an increase in crude protein content following germination of *L. angustifolius* after six days. Yates (1991, p. 45) confirmed that the protein content of the lupin sprouts without hull increased while the protein content of lupin with hull did not change notably. Sattar *et al.* (1989) found that the protein content of mung bean increased because of germination. They further stated that, "the marginal increase in total protein is not a real one, but merely the result of dissolution of starch content into the soaking medium (ibid, p. 114).

Since lupin contains very little starch, it is unlikely that any increase in protein in germinated sprouts would be the result of dissolution of starch content into the soaking medium (D. Petterson, personal communication 1991). There are however, low concentrations of other soluble components which may dissolve into the soaking medium, (Yates 1991, p. 19)

*Amino acids*

Amino acids are the building blocks for proteins. There are eight essential amino acids which our body must synthesize from the protein we eat. Another 14 amino acids are just as important, but can be synthesized by the body. Protein affects, and is essential to, proper digestion and assimilation of foods, cell renewal, immunity from disease and illness and proper liver function (Wigmore 1986, p. 7).

When raw legume seeds are germinated there appears to be changes in amino acid content. However, the sulphur-containing amino acids, methionine and cystine remain unchanged. Dagnia (1990, p. 39) found, following the germination of *L. angustifolius* for six days, that most amino acids decreased, including the sulphur-containing amino acids. Valine and aspartic acid were the only amino acids that showed an increase. Aspartic acid, a non essential amino acid, increased more than three fold following germination (Dagnia 1990, p. 39).
Sattar *et al.* (1989, p. 117) found that most amino acids in mung bean, including lysine, phenylalanine and isoleucine, increased during germination. However, the sulphur-containing amino acids did not change. They considered that an increase in amino acids may be because of the increased protein content. The higher levels of some amino acids in these studies were found to be not significant when data was expressed on a total protein basis (Sattar *et al.* 1989, p. 117). There is no increase in protein content because of germination. The energy is consumed with the germination process, the protein profile changes, but the protein content remains the same on a dry seed basis (D. Petterson, personal communication, December 1993).

Some protein changes occur during germination. They occur because the storage protein profiles of dry legume seeds differ from those of newly synthesized metabolic and structural proteins caused by germination. Although most of the legumes have a high protein content, the use of this protein is often low because of poor protein digestibility. The lower digestibility of legume protein is attributed to various factors, such as the presence of enzymes, inhibitors and the compact and complex structure of these proteins (Chang and Satterlee 1981, p. 1368). Germination is believed to increase the protein digestibility of legumes.

The most favourable changes which occurred during germination were decreases in the anti-nutrients, oligosaccharides and alkaloids. The decrease in oligosaccharides should reduce the likelihood of flatulence, caused by the ingestion of lupin seeds and sprouts. The decrease in the alkaloids should likewise reduce the likelihood that any bitter taste would be detected (Yates 1991, p. 62).

Germination improves the nutritive value of mung bean protein (White 1973 cited by Salankhe and Kadam 1989b, p. 75). Germination of mung bean for up to 96 hours resulted in a considerable decrease in trypsin inhibitor activity (Adsule and Barat cited by Salankhe and Kadam 1989b, p. 75). However, there was no change in the trypsin inhibitor during germination in *L. angustifolius* (Yates 1991, p. 58). This conflicts with the work of Dagnia (1990, p. 58) who reported that in *L. angustifolius*
the quality of lupin protein decreases following germination. The increase in protein is related to a decrease in trypsin inhibitor activity although the quality of protein decreases following germination.

Minerals

Minerals serve as the foundation for the body's overall metabolism. They are required for body building, the control of body processes, such as the transmission of nerve impulses and are an essential part of body fluids. Calcium is required by bones and teeth to keep them healthy and strong (Tull 1985, p. 26). Sprouts absorb minerals and trace elements from the water used to rinse them while growing and become a good source of easy to use minerals.

Ganesh Kumar et al. (1978, p. 78) found that when germinating mung beans, chick peas and cow peas for 24 and 72 hours, magnesium and calcium decreased. Kylen and McCready (1975, p. 1008) found when germinating alfalfa, mung bean, soy beans and lentils, that mineral content remained the same except for calcium which increased. They further claimed that the increase in calcium may be caused by the presence of calcium in the tap water used for germination.

Anti-nutrients

Many of the anti-nutrients contained in raw legumes can be destroyed or reduced by processing treatments such as heat and germination. Gupta and Wagle (1980, p. 385) reported that the germination of Phaseolus mungoreus resulted in trypsin inhibitor activity decreasing for up to nine hours, then increasing up to 72 hours and then decreasing again after nine days. At the onset of germination, trypsin inhibitor increased slowly because of the transformation of the dormant state of seed to the vigorous metabolic state.
Lipids

Dagnia (1990, p. 42) found that the fat content of *L. angustifolius* decreased following six days of germination. Yates (1992, p. 46) asserts that the fat content of *L. angustifolius* following six days of germination decreased more for sprouts with hull than for sprouts without hull. El-Habbal and Attia (1987, p. 960) claim there was no significant increase in the fat content of lupins (cv. Giza 1) after seven days germination, but there is not enough evidence to conclude that fat content for lupin decreased because of germination.

Vitamins

Vitamin C is important to the health of skin, teeth, and gums. It aids growth and development and protects other vitamins from oxidation (Wigmore 1986, p. 9). Sattar *et al.* (1989, p. 115) found that ascorbic acid is not detectable in ungerminated mung bean seeds. However, after germination for 48 hours ascorbic acid increased markedly with temperature to a maximum at 20 °C. The increase was greatest at 48 hours and decreased thereafter. However, it was still greater than the initial ascorbic acid content in the ungerminated seeds. Kylen and McCready (1975, p. 1008) reported similar results for mung beans, lentils and alfalfa sprouts after seven days germination. The ascorbic acid content of lupin has not been established. Preliminary studies by Petterson (Petterson and Crosbie, 1990) did not detect any of the vitamins at any stage of germination.

Vitamin A is essential for normal growth and development, for good eye sight, to keep mucous membranes in the throat and the digestive, bronchial, excretory system moist and free from infection, and for the maintenance and health of skin (Tull 1985, p. 9). Sprouts are usually rich in vitamin A containing up to four times more than do raw seeds. The vitamin A in the sprouts is supplied in the form of carotene which is converted into vitamin A in the intestine as needed. Carotene is non toxic in large quantities, whereas the synthetic vitamin A, or that found in fish oil, liver and
other animal foods, accumulates in the liver and can become toxic. Alfalfa sprouts
have more vitamin A than comparable amounts of tomatoes, lettuce, green pepper
and most fruits. Sprouted cabbage, clover, peas and mustard are also excellent
source of vitamin A (Wigmore 1986, p. 9). The vitamin A content of sprouted mung
and lupin is not known.

The B-group vitamins, thiamine (B1), riboflavin (B2) and niacin are abundant in
sprouted almonds, wheat, rye, sunflower and sesame. The vitamin B complex helps
the body digest carbohydrates and use the energy in them, promotes resistance to
infection and is also important for the nervous system.

Sattar et al. (1989) claim that riboflavin levels in mung bean reached a maximum
after 48 hours of germination, and thereafter decreased, but still contained more than
before germinating (1989, p. 115). Riboflavin increased in most legumes during
germination. Riboflavin is essential for normal growth and oxidation of food,
especially amino acids and fats (Tull 1985, p. 22).

Sattar et al. (1989) found that the thiamine content of mung beans increased when
germinated, reaching a maximum at two and three days. The biosynthesis of
riboflavin and thiamine was faster at ambient than low temperatures (Sattar et al.
1989, p. 115). Thiamine is required by the body for metabolism and general growth
(Tull 1985, p. 21).

The above evidence shows that the vitamin content of raw mung increases with
germination. The vitamin content of sprouted lupin is not known.

Summary

As the sprouting process proceeds, carbohydrates are transformed by the action of
enzymes into simple sugars. Complex proteins are converted into simple amino
acids and fats are converted to fatty acids which are easily digestible soluble
compounds. Vitamin C increases substantially during sprouting. In addition, sprouts
absorb the minerals and trace elements from the water used to grow and rinse them.
(Wigmore 1986, p. 5). Lupin also undergoes changes with germination. The changes in nutrients include an increase in fibre and polysaccharides, decrease in fat, sugars, anti-nutrients and oligosaccharides. Use of lupin sprouts over dry seed could be a benefit to food resources. With regard to an improvement in nutrient value with germination, lupin is comparable with mung for human consumption.
CHAPTER 4

Lupin and mung bean sprouts - comparison

Sprouts from beans and other seeds are produced by soaking the raw seeds and
growing them in a dark room with an intermittent supply of water and under
controlled environmental conditions of humidity and temperature. The process
results in a number of changes in the physical, chemical and nutritional properties of
the raw seed which have implications for its suitability as a food source. Such
related issues are now discussed. Different uses of mung and lupin sprouts are also
reviewed.

Mung (bean) sprouts

Mung sprouts are a staple in Oriental diets and have been widely used for thousands
of years (Wigmore 1986, p. 3; Courter 1973, p. 49). Bean sprouts are also used as a
vegetable by the Chinese and Japanese (Kittler and Sucher 1989, p. 261 and 277).

Mung sprouts can be used in many dishes as in main dishes, snacks, vegetables and
salads in Oriental and Western cooking. In Chinese cuisine the hull is usually
removed. Western users of mung sprouts tend to leave the hull on because it is seen
as a source of digestible fibre and minerals. Moreover, it is a tedious task to remove
the hull from mung sprouts (Courter 1973, p. 49).

The sprouts can be used as an ingredient in salad, sandwiches, green drinks, sprout
loaves and marinated vegetables (Wigmore 1986, p. 33; Courter 1973, p. 49). They
can be eaten raw, but a few seconds' steaming will remove any beany taste. While
cooking as a stir-fry, they are added only at the last moment, otherwise they tend to
wilt (Courter 1973, p. 49).

The length of sprouts at harvest is a matter of personal choice. Mung sprouts can be
harvested at almost any time from the moment the shoot appears until they are 10 cm

-50-
long when they are normally juicy and plump. The sprouts start to wilt if left to grow much longer (Courter 1973, p. 49).

*Lupin sprouts*

Lupin sprouts have been grown by a number of workers and were tested for sensory acceptability in soups, pickles, spring rolls and as salad ingredient.

Lee (1986, p. 68) when examining lupin germination, found that the colour, freshness and crispness of lupin sprouts were excellent. Yu et al. (1985, p. 177) found similar results, and their study reported that lupin sprouts had superior eating qualities and higher moisture content when compared with soybean sprouts. Yates (1991, p. 93) compared soup made from lupin kernels and lupin sprouts and found that the sprout soup was less acceptable. Yates (1992) compared lupin sprouts and mung sprouts as pickled sprouts (a Vietnamese use of sprouts) and found that pickled lupin sprouts were as acceptable as mung. Lupin was more beany and less salty than mung, but equal in all other respects (Yates 1992, p. 23). Sprouts were included as a major ingredient in spring rolls and lupin was found to be as acceptable as mung sprouts. The lupin sprouts were slightly less crispy and more beany, but the difference was not very large (Yates 1992, p. 25). Stir-frying is the most popular method of cooking sprouts in Oriental cuisine. The lupin sprouts were not as acceptable as mung sprouts when used as an ingredient in stir-fry vegetables. They were found to be less chewy and had a less salty flavour (Yates 1992, p. 26). Yates (1992) harvested lupin sprouts at different stages of growth. While comparing day 4 and day 6 lupin in the 'pickled sprouts', spring rolls and stir-fry, she concluded that there was no major difference in the respondents perception of day 4 and day 6 lupin sprouts. This means that it may be adequate to germinate lupins for only four days. This would make them more economical to produce and would improve their post-harvest shelf-life in comparison with germinating them for six days.
One possible impediment to the use of lupin as a human food ingredient could be that, until recently, the name lupin has only been associated with its use as an animal fodder. However, Zweck (1988) and Yates (1991) suggest that there seems to be no real risk in making known the inclusion of lupin in any food product. An attitudinal study found that the name lupin was perceived as being positive as a name for inclusion as a food ingredient (Yates 1991, p. 13). The study further concluded that the stated nutritional properties of lupin would certainly encourage consumers to buy a product containing lupin. Moreover, the health value of lupins could be used as a marketing tool for lupin promotion (Yates 1991 p. 108).

**Commercial sprout manufacturers in Western Australia**

In Western Australia, there are few commercial sprout producers. It is difficult to get accurate figures of the total sprouts produced in Western Australia because they do not go through the central markets at Canning Vale.

There are other small scale sprout manufacturers who produce almost 3500 to 4000 tubs of sprouts a week. The sprouts manufactured in this State include alfalfa, mixed alfalfa, (alfalfa and radish), lentils, stir-fry mix (pea, adzuki and lentil). These sprouts are grown hydroponically and organically. About 4 to 4.5 tonnes of sprouts are sold in Perth every week. This research was done with the active co-operation and assistance of one of the major sprout processors in Perth. For reasons of confidentiality, this company will henceforth be called by the pseudonym of JAS. JAS has about 50 per cent of the total market in Perth.

**Comparison of raw material costs**

The major cost factor per unit of product which concerns the food processor is the cost of raw material. Raw lupin or mung seeds are the major raw material. Cheaper alternative raw materials will only be acceptable to the sprout grower if it is available and is of good quality for the intended purpose.
Availability, quality and price of mung seed for sprouts

The production of mung bean sprouts is a high risk crop and has many problems associated with quality. The major use of mung seed is to produce sprouts. There is continuous research into the production of better varieties. Furthermore, new outlets for mung bean uses, other than sprouts, have been explored. This might make the future less troublesome for the mung grower in the future (Pestna 1993, p. 250). Nevertheless, this may not reduce the existing problems for Western Australian sprout manufacturers for whom quality of mung is the prime issue.

Australian mung bean production is about 15 kilotonnes a year. The major source of production is centred around the Dawson/Callide region, south-west of Rockhampton in Queensland. There are also smaller producing areas in New South Wales, the Darling Downs and the Central Highlands in Queensland and the Northern Territory (Pestna 1993, p. 250).

Mung is priced at $400 per tonne in the eastern States. The prices in Western Australia during the harvest season range from $740 to $800 per tonne as there are additional transport and other trade costs. The wholesale price normally rises to $1350 per tonne during the off season. There is a great difficulty in obtaining good quality, uniform sized seeds for sprouting in Western Australia (P. Smith JAS, personal communication, November 1992).

Availability, quality and price of lupin seed

The total production of lupins for 1991/92 for Australia was 934.4 kilotonnes. Western Australia contributed a major share of this by producing 868 kilotonnes (Pestna 1993, p. 245).

About 500,000 tonnes of lupin are received from growers for sale by the Grain Pool of Western Australia each year. Most of this is sold for commercial stock feed on the international market. Lupin is normally priced at around $200 per tonne depending on prices in the international market. The cleaning and grading of lupin seed for
human consumption can bring the cost to $300 per tonne as there is some loss caused by cleaning and grading. It is estimated that up to 3 per cent is lost as substandard seeds, 10 per cent of small seed and 1 per cent of non lupin material. This may not be important for animal feed, but is critical for sprouting purposes (D. Petterson, personal communication, July 1993). This means that clean and graded lupin seed of uniform quality could be available in Western Australia at around $300 per tonne.

Advantages of lupin over mung for growing sprouts

Lupin has the advantage of being locally produced in Western Australia. Clean, graded lupin seed of uniform quality would be available at $300 per tonne, whereas mung is available at a minimum of $700 per tonne. In addition, there is a great difficulty in obtaining good quality graded mung seed for the purpose of sprouting because of the remoteness of the growing sites and the inability of the sprout processor to enforce adequate quality control practices over eastern States mung bean growers.

Lupin sprouts grown under domestic and laboratory conditions (Yu et al. 1985, Lee 1986 and Yates 1991) were found to be as acceptable as mung sprouts as regards value-adding. It was found by these workers that lupins have a 7.5 fold weight increase while mung and soybeans have a 5.5 fold increase after sprouting. This should make lupins very competitive in the market-place. Sensory evaluation suggests that lupin sprouts are as acceptable as mung sprouts and that mung sprout is reasonably popular with sprout eaters. This poses the following questions:

1. Could lupin sprouts be grown commercially under similar conditions to mung sprouts?
2. Would the commercial production of lupin sprouts be economically profitable?
3. Would commercially grown lupin sprouts be an acceptable alternative or substitute to mung sprouts in the market-place?
To answer these questions research was done into three components of the commercial sprouting process, viz:

(i) Factory environment: A description and evaluation of a commercial environment suitable for the growing of lupin sprouts.

(ii) Sprout production environment: A comparative evaluation of lupin and mung sprouts considering raw material costs, production yield, growing characteristics and quality.

(iii) Consumer research: A comparison of lupin and mung sprouts by potential retail (Caucasian and South East Asian) consumers of fresh sprouts.

It may be feasible to grow lupin sprouts in a factory environment designed to grow mung sprouts. If the facilities are found to be suitable for lupin sprouting, then the processors have the potential advantage of either substituting lupin for mung, or of introducing a new line of product to the market. Even if mung and lupin sprouts are found to be more different than similar, then this could mean that lupin sprouts could still be marketed as a different type of sprout and perhaps directed to different target groups or used for different purposes. In either case, both the producers and the down-stream investors could derive financial benefits from this development of a new product.
CHAPTER 5

Factory environment: description and evaluation of the commercial physical environment

JAS

JAS is a food processing company with a factory located in suburban Perth. Mung sprouts are one of the major products produced by the company and JAS has a substantial share of the Perth sprout market. The JAS factory is the model used in this discussion. However, any similar factory environment could be evaluated applying the same methods.

Technical Manual No. 25, September 1989 - ‘Guidelines for the hygienic manufacture, distribution and retail sale of sprouted seeds with particular reference to mung beans', published by the Campden Food and Drink Association (UK) and edited by K.L. Brown and C.A. Oscar. It provides guidelines for satisfactory mung sprout production, hence forth referenced for simplicity as Campden. The physical environment and procedures used by JAS were evaluated insofar as they conformed to the Campden Guidelines.

The information so derived was then supplied to senior management in the form of recommendations and suggestions as to how the JAS operation may be improved.

Materials and methods

Sprouted mung beans (Vigna radiata) commonly known as bean sprouts, are commercially manufactured in Western Australia, but only small quantities of mung beans are grown in Western Australia.

Supplies of mung, the small green coloured seeds used for growing bean sprouts in Perth, come from Queensland. The mung beans used in the study were supplied by JAS Industries. The lupin (Lupinus angustifolius cv. Gunguru) seed was purchased.
from the Moora Seed Works who graded the seed over a 5.5 mm screen to remove small and immature seeds. A schematic presentation of the floor plan of the sprout growing facility is shown in the Figure 4 (size of area not to scale).

Production environment: description

![Schematic floor plan of the JAS sprouting facility.](image)

The areas used for growing sprouts (C-growing area, D-washing area, E-packing area) are separated by walls from the rest of the JAS factory premises. The storage area for beans (B) is located near a main entrance as it is a convenient place to unload the raw material. The growing room (C), which is a dark and warm, is kept closed most of the time. The soaking area (B) is within the growing room. The growing room is separated by a wall from the washing area (D) which comprises an open service lane and a 60 cm wide concrete channel. The packing area (E) is an open space next to the washing area while the cool room (G) is near the exit. The packing materials and other supplies are stored in room (F) adjoining the growing and washing areas. The water tank (H), used for irrigation purposes, is also within the general enclosed area.
Manufacturing of sprouts in a commercial environment

The commercial production of bean sprouts involves the following sequential stages:

A flow chart of the process is shown in Figure 5.

Figure 5. Flow diagram showing manufacturing process of sprouts.
Equipment

Preparation equipment:

The following equipment is used in the preparation of mung (and lupin) sprouts at JAS.

Soaking containers

These are 200 litre plastic drums. The containers have a hole of some 2 cm diameter near the base of the container. The hole is covered with triangular piece of stainless steel 1 mm² wire mesh to prevent mung beans from passing through while draining.

Water tank

The water used for soaking, irrigation and washing is stored in a separate concrete tank which can hold up to 36 tonnes of water. The water tank is shown by H in Figure 4. One kilogram of pool chlorine (calcium hypochlorite) is added every day to disinfect the water. The water used for irrigation is supplied at room temperature while chilled water is used when washing the grown sprouts.

Growing room equipment

Sprout growing chambers and trays

The growing chambers are small rooms constructed of PVC corrugated sheets. They are about 2 m wide x 4 m long x 2 m high. The floor of these chambers is raised about 30 cm above the ground. The construction of the floor consists of 50 mm wide plastic batons. These batons are mounted on angle sections with plastic separators leaving a gap of 2 mm for easy drainage of water.

Overhead shower spray watering system

The water shower system is mounted on an overhead trolley. The watering rate is controlled by an automatic timer.
**Belt conveyor**

A 30 cm wide belt conveyer runs throughout the length of the room to carry harvested sprouts for washing.

**Washing system**

**Water channels, spiked rollers and conveyor**

The concrete washing channel is divided into three sections with partitioned walls. Spiked rollers are mounted on top of the side walls which move clockwise to give a forward movement to the floating sprouts. The first section, being longer, has four such rollers while the other sections have two each. Towards the end of each section an inclined belt conveyor is mounted on two rollers. This belt conveyor has dog-legged spikes mounted upon it and moves anti-clockwise to lift and move the sprouts to the next section. The washing channel holds two tonnes of water when full.

**Packing equipment**

This includes a table with a spout attached and on which the bags are placed for packing, weighing scale, trolleys and plastic bags.

**Cool room**

The cool room (marked G in Figure 4) is used for the storage of washed sprouts which are held at 4°C ready for distribution.

**Layout of equipment**

The layout of the sprout manufacturing plant is described in the Figure 6.
The manufacturing process can be divided in three stages; preparation, sprouting and harvesting.

Preparation

The dry seeds are weighed in 100 kg to 120 kg lots. The seeds are visually inspected and any foreign material is manually removed. About 25 kg of seeds are placed in each soaking bucket which is then filled with chlorinated water. Broken seeds, loose seed coats and other unwanted materials such as hay, straw, threads (from the field) float to the surface and are manually removed. After soaking for eight hours, the water is drained out and discarded. This process of rinsing seeds serves two functions. Firstly, it serves to remove any non-seed material and, secondly, to help wash microflora and or any external contaminants from the surface of the seeds. As most of the microbial contamination is likely to be on the surface of the seed, so
Surface decontamination is very important to reduce both the total count and the incidence of pathogens. (Brown and Oscroft (Eds) 1989, p. 5). Rinsing is repeated only if the seeds are very dirty, but normally one rinse is adequate. Seeds are then soaked in 200 litres of chlorinated water for an average of eight hours. 'The length of soak time depends upon the temperature; longer times are required at lower temperatures' (Brown and Oscroft (Eds) 1989, p. 5).

During the period of soaking, the seeds swell and double in volume. The excess water is drained off without disturbing the seeds. Seeds are allowed to stay for four more hours in the same containers. At this stage the swollen seeds start germinating. The seed coat is ruptured and the tiny hypocotyl becomes visible.

These germinated seeds are transferred to the sprouting or growing chambers.

**Sprouting**

Sprout development normally takes place under intermittent irrigation in the dark room at a controlled temperature (usually in the range of 20-30°C) for a controlled time (usually 4 to 7 days) (Brown and Oscroft (Eds) 1989, p. 6). Figure 7 shows a front view of the sprouting chambers of JAS with watering system and sprouts.

![Figure 7. Front view of sprouting chambers with watering system and sprouts](image-url)
Sprouting takes about 5 to 6 days in a dark room. The germinated seeds form a layer of about 8 cm on the floor which finally swells up to 100 cm high when the sprouts are ready for harvesting. Throughout the sprouting process, seeds are watered every four hours with good quality water. This prevents overheating of the growing mass and washes the growing sprouts. Cooling is necessary otherwise the temperature will rise and facilitate microbial spoilage. The washing also helps to remove any microflora that might have colonized the growing sprouts. However, too much water is detrimental as it attracts moulds which thrive on the sprouts and makes them slimy and unattractive. The rule of thumb is that the sprouts should always be moist, but not sit in water throughout the growing process (Courter, 1973, p. 24). The room temperature is controlled to about 24°C.

During the growing process, the sprouts are not unnecessarily disturbed. Regular inspections are done by trained staff who pick small quantities from the sprout mass. The sprouts are visually inspected for 'root growth' and or slimy roots and for any off-odours. The root growth (Table 6) provides a check and guide as to whether the four hour watering schedule is 'too much' or 'too little' (W Ming, personal communication, 1992).

<table>
<thead>
<tr>
<th>Root growth (Visual inspection)</th>
<th>Reason</th>
<th>Control measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin, long with several long root hairs.</td>
<td>Sprouts are stressed for water. Formation of long root hairs suggests quantity of water is insufficient</td>
<td>Increase the water quantity and/or decrease the time gap between two waterings</td>
</tr>
<tr>
<td>Thin, long with one or two root tiny hairs beginning to form</td>
<td>Water is sufficient for the sprouts</td>
<td>Do not disturb either water quantities or timings.</td>
</tr>
<tr>
<td>Thin, long, but slimy at the ends with no root formation. A peculiar foul smell from the sprouts.</td>
<td>Water is more than required by the sprouts. Too much water attracts microbes</td>
<td>Decrease the water quantity per watering and/or increase the time gap between watering cycles.</td>
</tr>
</tbody>
</table>
Harvesting and washing

The mature sprouts are harvested manually and then washed through a mechanical process. In about six days, the mung sprouts become ready for harvesting. The whole growing chamber is dominated by a large sprout mass which is about 90 to 100 cm high. The top 10 cm layer, which is usually dry and brownish, is often discarded as being unsuitable for commercial consumption. Sprouts are harvested manually by trained staff and placed on a belt conveyor to carry them into the washing channels.

The objective of washing the sprouts is threefold. Firstly, it separates, ventilates and cools down the sprouts thus stopping further growth. Secondly, it removes the loose seed coats and any poorly grown sprouts. Finally, it washes microflora from the external surface of sprouts.

Figure 8 shows the cross sectional view of the washing and packing equipment. The washing channel has three sections with a set of spiked rollers. The water remains stationary in the channel and water from one section does not overflow into the next section. The strong healthy sprouts float on the water and are pushed forward with the spiked rollers. Movement of rollers is shown by arrows in the Figure 8. At the end of the washing channels, the sprouts are lifted by spiked rollers and transferred into another chamber containing clean water. In the same way, they are washed in three or four water channels constructed in sequence. The loose seed coats and unhealthy sprouts either settle down on the floor or are washed away with continuously flowing water. The last section contains cold water. One cup of sodium metabisulphite is added to 100 litres of water for the final rinse and to keep the sprouts fresh longer and to arrest microbial growth.
Packing

Packing is done at the end of the washing cycle. The sprouts are collected on a table with a slanted top to facilitate the drainage of any surplus water. One edge of the table has a chute on which a plastic bag is hooked and sprouts are dropped into the bag. The plastic bags have a few holes at the bottom for ventilation and drainage. These are weighed in 5 kg and 3 kg packs and are then placed onto multi-tiered trolleys. The bags are left open on the top and are stored in cool room (4°C) immediately ready for retail distribution. The bags have no labels to describe the name of the product, its weight, the 'use by' date or the batch manufacture date.

Evaluation of the factory environment check list on the basis of the Campden Technical Manual

The Campden manual includes a series of relevant questions which were asked of JAS management and staff to evaluate current practices. A validity check was made by direct observation of existing practices wherever possible.
Questionnaire

Question: Are there any guidelines for the hygienic manufacture of sprouts being used?

Answer: No specific guidelines are available to JAS for the manufacture of sprouts.

Comments: The lack of written standards or procedures make it difficult for production staff to evaluate the acceptability of various practices adopted in the production process. No quality control measures can be established if there are no existing guidelines to use for comparison purposes unless these are developed by the individual processor. A set of guidelines should be used to ensure the consistent quality of the final product.

Question: What is the source of seed supply?

Answer: Queensland. There is only one supplier.

Comments: If the manufacturer has to depend upon the services of one supplier then the manufacturer has no advantage of competitive buying and often has to compromise on raw seed quality to keep costs in an affordable range. Alternate sources of supply should be sought and certificates of quality of raw seeds including germination rate should be compulsory. The latter recommendation requires an inspection source at the point of sale.

Question: Are the dried seeds sampled and tested for potential microbiological contamination?

Answer: Seeds are generally tested by the supplier and certificates are provided. Irregularities do occur sometimes when the supplier does
not provide the certificates. The sprout manufacturer however, has little choice but to accept the seed supplied.

Comments: In the case of crop failure or quality problems it is hard to establish if the real cause of microbial contamination is in the quality of raw seed or as a result of other defects. Services of an unbiased seed testing centre, such as the Department of Agriculture, Western Australia, could be used as an alternative. If possible, JAS should set up facilities for microbiological testing of raw seeds.

Question: How are the seeds stored in the premises?

Answer: Seeds are stored in a shed near the entrance of the workshop.

Comments: There is no control on the entry of personnel and no person is allocated security and door closing responsibilities. There are no humidity, temperature and vermin controls.

The quality of seed may deteriorate in storage because of uncontrolled storage conditions.

Question: What control measures are being used for bird, rodent and insect control?

Answer: JAS follows the insect control measures as specified by the Health Department.

Comments: Direct observation showed that there was poor control of birds and rodents. Contamination of seeds by birds and rodents can cause serious health hazards. A better controlled set of procedures need to be introduced.

Question: How are the seed stocks rotated or used?

Answer: JAS policy is for rotation on the basis of 'first in, first out'.
This appears to be an accounting practice only as the seeds stocks are not marked with their receipt date. This makes it difficult to ensure that stock rotation is done in practice. In the case of quality problems, the defective supplies cannot be identified. It becomes difficult to provide prompt feedback to the supplier in relation to quality problems. A batch control and rotation system should be introduced.

Question: Is the water pipeline capable of being dismantled for cleaning or on-line (CIP) cleaning?

Answer: Yes, the pipeline can be dismantled.

Comments: This facilitates easy cleaning of the watering system and does not require any change.

Question: How often are the storage tanks cleaned?

Answer: The storage tanks are cleaned once per year.

Comments: This appears adequate and it may not be feasible to clean the pipe at more frequent intervals.

Question: How often is the water disinfected?

Answer: Water is disinfected once a day.

Comments: Disinfection once a day is adequate.

Question: What are the disinfectants used and in what quantity?

Answer: Pool chlorine (calcium hypochlorite), One kilogram per day (in 36 tonnes of water).

Comments: This is a very high level of disinfectant. This seems to be an unnecessary cost without any gains in quality. Campden recommends that the irrigation water should be chlorinated at the...
Levels of 2 to 4 ppm free chlorine. Levels of free chlorine should be tested every day and the amount of disinfectant should be adjusted to avoid over use of disinfectant.

Question: Is there any procedure for cleaning seeds before soaking?

Answer: Yes, the seeds are visually inspected. Any foreign material is picked up manually. Seeds are washed until they are thoroughly clean.

Comments: This is adequate when used complementary to the quality control methods exercised by the supplier.

Question: Are any surface decontaminants used and which ones?

Answer: No surface decontaminant used.

Comments: Most of the microbial contamination is likely to be on the surface of the seed, so surface decontamination is most important to reduce the total count and surface incidence of pathogens. Seeds should be initially soaked in water containing a high level of surface decontaminant, for example, Campden recommends total chlorine of 100 to 200 ppm. Adequate contact time (minimum recommended 30 minutes) should be allowed for inactivation of the surface microflora. This time should be controlled and recorded. Campden further recommends that the seeds should be drained and then rinsed until the water runs clear before soaking.

JAS needs to consider this additional step in the process to achieve consistent quality of sprouts.

Question: Are the containers used for germination i.e. sprouting chambers being cleaned and disinfected before use?
Answer: All the containers used are recyclable and are washed with water before use. However, no detergents are used for cleaning the containers.

Comments: Deposits of mould on the container surface cannot be controlled by washing with water alone. This could cause contamination. There is a need to make physical use of detergents and mechanical aids to remove more difficult soiling. Detergents that could be used include a moderately alkaline detergent such as sodium metasilicate. Surfaces should then be thoroughly rinsed.

Question: Is the construction of floor and walls smooth, impervious and free from cracks, splits, damage and holes?

Answer: Yes, JAS has used reasonably good construction material in the sprout manufacturing area.

Comments: Manufacturing facilities of JAS in this context are adequate.

Question: What are the cleaning, disinfection and maintenance schedules used for each of the following:

<table>
<thead>
<tr>
<th>Questions</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>a   Floors</td>
<td>Soon after the harvesting operation is completed.</td>
</tr>
<tr>
<td>b   Walls</td>
<td>Once a year.</td>
</tr>
<tr>
<td>c   Ceilings</td>
<td>Not required.</td>
</tr>
<tr>
<td>d   Lighting system</td>
<td>When it breaks down.</td>
</tr>
<tr>
<td>e   Tube, bins, trays and other equipment</td>
<td>Pressure hosed with chlorinated water.</td>
</tr>
<tr>
<td>f   Drainage system</td>
<td>Pressure hosed.</td>
</tr>
<tr>
<td>g   Waste material collection system</td>
<td>Waste is immediately cleaned.</td>
</tr>
<tr>
<td>h   Insect and pest control system</td>
<td>Once a year.</td>
</tr>
<tr>
<td>i   Harvesting and washing equipment</td>
<td>Soon after finishing the operation.</td>
</tr>
<tr>
<td>j   Packaging equipment, material and surroundings</td>
<td>Soon after finishing the operation.</td>
</tr>
<tr>
<td>k   Cool room</td>
<td>Swept daily.</td>
</tr>
</tbody>
</table>

Comments: The cleaning procedures are usually satisfactory and in accord with the Campden standards.

Question: Are any personnel hygiene regulations being followed?
Yes, the regulations specified by the Health Department are followed.

Workers and staff generally seemed aware of these regulations and conform to their requirements.

What training is provided to the employees for good hygiene practices?

Two trained employees have been involved in the job for many years. No formal training is provided about hygienic practices to handle sprouts.

Although the employees are aware of health regulations the lack of formal training may limit their appreciation and understanding of the need for close adherence to the recommended standard and of proper practice. Staff training should be upgraded.

Are there any special clothes and footwear specified and provided?

Yes, special clothing, gloves and footwear is provided for the production area and conforms to their proper use.

JAS employees are conscious of wearing special clothes and footwear.

Are there proper hand washing facilities available near the production area?

Yes, foot operated taps, soap and disposable paper towels for hand drying are provided.

Hand washing facilities are adequate and used by the staff.

Is there any regular medical examination to check for sickness or injury?

No regular medical examinations are done by the company.
Comments: Workers when suffering from or infected by influenza, viruses, open wound on hands could spread or transfer the disease to other employees working in the section or to the consumer through contaminated sprouts. There is a need to introduce a system of medical examinations of staff.

Question: Are the sprouts tested and sampled for microbiological quality?

Answer: There are no facilities available on the premises.

Comments: This could mean the risk of contamination without JAS being able to determine whether the problem lay with the raw seeds, water supply, poor preparation or microflora. If possible, JAS should install sets of practices and procedures for the testing of the final sprouts before distribution.

Results and discussion

The results are summarized in Table 7 and are comparable to the Hazard Analysis Critical Control Point (HACCP) as advised by the Campden Food and Drink Research Association.

HACCP describes a system of control for assuring food safety. It is sometimes difficult to identify hazards by traditional inspection and quality control procedures. In the case of new operations, it is important to identify areas of concern where failure could cause financial loss for the commercial manufacturer. HACCP provides a structured and critical approach to the control of identified hazards.
<table>
<thead>
<tr>
<th>Control point/control measure</th>
<th>Compliance</th>
<th>Comments or implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material</td>
<td></td>
<td>The poor storage conditions may lead to several problems including dampness which may cause mould or bacterial growth. Birds or insects may contaminate the seeds by infecting them with <em>Pestacrosis</em>. Rodents can infect the seeds with <em>Salmonella</em> as can birds.</td>
</tr>
<tr>
<td>Dried beans</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Dry storage/humidity control and moisture control in beans</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Bird, rodent and insect control programme</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Selection of supplier of good quality seed</td>
<td>Partial</td>
<td>While care is taken to buy healthy quality seeds from the supplier, competitive marketing conditions sometimes result in substandard purchases.</td>
</tr>
<tr>
<td>Microbiological tests on dried beans</td>
<td>Nil</td>
<td>In JAS there are no microbiological test facilities available for the detection of pathogens in dried seeds.</td>
</tr>
<tr>
<td>Inspection, sieving and washing</td>
<td>Partial</td>
<td>Sieving is not required.</td>
</tr>
<tr>
<td>Packaging material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bird, rodent and insect control programme</td>
<td>Partial</td>
<td>Storage on open shelves specially with other material such as dry powder chemicals may cause or result in cross contamination.</td>
</tr>
<tr>
<td>Clean storage environment</td>
<td>Partial</td>
<td>Storage on open shelves can cause contamination by dirt.</td>
</tr>
<tr>
<td>Soaking and germination of seeds</td>
<td></td>
<td>This step needs to be added in the process to consistently achieve same quality product.</td>
</tr>
<tr>
<td>Surface decontamination of seeds</td>
<td>Nil</td>
<td>An unclean environment can cause growth of surface microbial contamination.</td>
</tr>
<tr>
<td>Cleaning and disinfection of recycled soaking and germination containers</td>
<td>Partial</td>
<td>Infected recycled containers could cause bacterial infections by cross contamination.</td>
</tr>
<tr>
<td>Disinfection of water supply</td>
<td>Full</td>
<td></td>
</tr>
<tr>
<td>Control point/control measure</td>
<td>Compliance</td>
<td>Comments or implications</td>
</tr>
<tr>
<td>------------------------------------------------------------------</td>
<td>------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Growth of bean sprouts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of disinfected irrigation water</td>
<td>Full</td>
<td>This prevents excessive microbial proliferation.</td>
</tr>
<tr>
<td>Cleaning and disinfection of recycled growth containers</td>
<td>Partial</td>
<td>If growing containers are not thoroughly disinfected with strong disinfectants, multiple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bacterial growth may occur during longer periods of use.</td>
</tr>
<tr>
<td><strong>Harvesting/washing of sprouts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning and disinfection of spades used for harvesting</td>
<td>Full</td>
<td>Prevents contamination during harvesting.</td>
</tr>
<tr>
<td>Application of control measure before harvesting</td>
<td>Full</td>
<td>Prevents contamination from wash water.</td>
</tr>
<tr>
<td>Chlorination of wash water</td>
<td>Full</td>
<td>Prevents proliferation of micro-organisms by cooling down the sprouts. Chlorine levels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>adequate to kill most microbial contaminants.</td>
</tr>
<tr>
<td>Chilling and chlorination of wash water</td>
<td>Full</td>
<td></td>
</tr>
<tr>
<td>Cleaning and disinfection of wash tank system daily at the end of</td>
<td>Full</td>
<td>Prevents contamination from wash tank surface.</td>
</tr>
<tr>
<td>production. Cleaning and disinfection of collection bins.</td>
<td>Full</td>
<td>Prevents contamination from collection bins.</td>
</tr>
<tr>
<td><strong>Packing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel hygiene control</td>
<td>Full</td>
<td>Good sanitary handling practices prevent contamination.</td>
</tr>
<tr>
<td>Regular hand washing</td>
<td>Full</td>
<td>-do-</td>
</tr>
<tr>
<td>Regular change of gloves</td>
<td>Full</td>
<td>-do-</td>
</tr>
<tr>
<td>Regular cleaning and sanitation of equipment.</td>
<td>Partial</td>
<td>Pressure hose cleaning may cause cross contamination.</td>
</tr>
<tr>
<td>Design of factory layout and drainage system.</td>
<td>Full</td>
<td>Care in the cleaning and the sequence of cleaning units to avoid splash dispersion of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>micro-organisms.</td>
</tr>
<tr>
<td>Controlled movement of staff and equipment.</td>
<td>Full</td>
<td>Well designed layout and controlled staff movement prevents cross-contamination from</td>
</tr>
<tr>
<td></td>
<td></td>
<td>raw material, germination and growing areas.</td>
</tr>
<tr>
<td>Use of metal detector</td>
<td>Nil</td>
<td>Metal fragments from the equipment may go unnoticed causing problems.</td>
</tr>
</tbody>
</table>
Table 7 continued...

<table>
<thead>
<tr>
<th>Control point/control measure</th>
<th>Compliance</th>
<th>Comments or implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage under chill $5^\circ$C ± $2^\circ$C</td>
<td>Full</td>
<td>Prevent microbial growth and extends shelf life. Note: Shelf life at room temperature = 1 day. Shelf life in cool room = 4 days.</td>
</tr>
<tr>
<td><strong>Distribution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chill distribution chain $5^\circ$C ± $2^\circ$C</td>
<td>Partial</td>
<td>Delicate sprouts can be spoiled by high temperatures specially in summer. This can result in use of out-of-date products.</td>
</tr>
<tr>
<td>Date labelling and stock rotation control</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td><strong>Consumer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning instructions to the consumer on storage, shelf-life and preparation printed on the package</td>
<td>Nil</td>
<td>No instructions are given. Clear instructions to consumer would help healthy storage and increased use of sprouts.</td>
</tr>
</tbody>
</table>
Conclusions and recommendations.

From my analysis of the factory environment in relation to the Campden Food and Drink Research Association's guidelines, the following recommendations are made to further improve, control and obtain a more consistent quality of sprouts.

- An automatic door closer should be fitted to the door of the raw material storage shed. This will prevent entry of birds into the store.

- All stocks should be labelled with lot number and date of receipt. The CODEX system should be used to ensure the first in first out principle for stock rotation.

- Irrigation water should be tested periodically to calculate the optimum level of disinfectant required. This will save costs caused by excessive use of disinfectants.

- JAS needs to consider the additional step of surface decontamination in the process to reduce the total count and surface incidence of pathogens to achieve consistent quality of sprouts. Seeds should be initially soaked in water containing a high level of surface decontaminant, for example, the Campden Food and Drink Research Association recommends total chlorine of 100 to 200 ppm. Adequate contact time (minimum recommended 30 minutes) should be allowed for inactivation of the surface microflora. This time should be controlled and recorded. The Campden Food and Drink Research Association further recommends that the seeds should be drained and then rinsed until the water runs clear before soaking.

- The recyclable containers should be washed with strong bleach or disinfectant at regular intervals and should be sun dried or exposed to ultra violet light.

- Formal training in good hygiene practices should be provided periodically to update the knowledge of employees with current standards.
• The Company should adopt the policy of not permitting sick people to work in food handling area. It may be noted that minor diseases like the common cold can cause problems.

• Packaging materials should be stored in closed cupboards. Care should also be taken to store chemicals in a different area.

• A vigorous cleaning routine as outlined by Giese should be followed:

Giese (1991) outlines four steps that should be undertaken to clean and sanitize a food processing area:

1. Pre-rinse the area with the water under high pressure.

2. Physical use of detergents and mechanical aids to remove more difficult soiling. Detergents which could be used safely include a moderately alkaline detergent such as sodium metasilicate.


4. Application of a sanitizer before food processing to prevent contamination of food by killing micro-organisms on the surface. A popular sanitizer is a sodium hypochlorite solution, but care must be taken that there is no build up of resistance to it. The effectiveness of a sanitizing solution also depends on the exposure time, pH, temperature, concentration and water hardness. The surface to which the sanitizer is applied, should always be cleaned and rinsed first as the soil on equipment and benches can reduce the effectiveness of the sanitizer (Giese 1991, p. 74-77).
CHAPTER 6

Growing characteristic of lupin and mung sprouts under standard factory conditions

Introduction

The suitability of the existing JAS facilities for the production of market quality lupin sprouts are herein assessed. Despite the lack of some quality controls mentioned in the previous chapter, it is clear that the current facilities at the JAS factory allow production of a market quality sprout from mung beans. It would be of considerable commercial value to JAS to ascertain the extent to which the existing production system could be used to produce lupin sprouts as an alternative to mung bean sprouts, or as an additional item of production.

To determine the possibility of producing lupin sprouts commercially, a series of experiments was designed to compare the growth of lupin and mung sprouts grown under identical conditions. Because of the financial constraints associated with the conduct of full scale production runs (100 to 120 kg of raw seed), a series of preliminary (small scale) experiments with 3 kg batches of raw seeds was conducted twice. Upon completion of the pilot studies, full scale production runs of lupin sprouts were evaluated in comparison with mung sprouts produced under identical conditions. Measurements were made of both the growth and the physical environments and of any changes which occurred during the sprouting process.
Experimental series

Small scale production: The atmospheric environment in the growing sprouts

Temperature, light and humidity

Failure to provide an appropriate environment for growing sprouts can result in serious microbiological contamination, high wastage rates and a poor quality end product.

The three main environmental factors which determine sprout quality and volume are lighting, temperature and humidity. In commercial sprouting, all of these are controlled by the processor.

Under natural growing conditions, germinating seeds are subjected to diurnal temperature and light patterns which involve a periodic and systematic variation in lighting and temperature conditions. Commercial growing of sprouts usually takes place in dark, isolated rooms or chambers at almost 100 per cent humidity. Temperature is usually regulated by means of cooling systems and insulation and kept at between 21°C to 23°C.

While many of the reasons for selecting these particular parameters appear to be based on tradition, others have a scientific basis. For example, research showed that mung (or Chinese) sprouts are more tender when grown in the dark as exposure to light makes them tougher. This is because photosynthesis stimulates the development of cellulose (Wigmore 1986, p. 48). Yates (1992, p. 16) studied the relationship between ambient temperature and lupin sprout quality and concluded that the best yield was at 24°C. At higher temperatures, microbiological growth led to spoilage and a high wastage rate.

Cohen (1958) analysed the effects of changes in the temperature of the sprouting mass. He concluded that it was the changes which occur in the temperature of the
sprouting mass, rather than ambient temperature *per se*, which was the major determining factor resulting in spoilage.

While both ambient and sprout mass temperatures appear to be critical determinants of sprout quality, the lack of monitoring or detailed recording systems at JAS means that little information is available about the environmental conditions operating in the JAS sprouting chambers.

JAS staff (personal communication) considered that the chamber temperature was held within an acceptable range, but that there were times, at the height of summer, when they experienced high spoilage rates. It seems likely that this was caused by an increase in the ambient and sprout mass temperatures.

A need was seen to monitor both room and sprout mass temperatures during the sprouting process for both lupin and mung sprouts. It is possible that any differences between the two could be because of the different metabolic behaviour of the two species.

It should be understood that the experiments were conducted in parallel with the commercial run. The results refer to temperature changes which occurred under the conditions used for the commercial growing of mung sprouts. It was not possible under these circumstances to manipulate variables in an orderly way. Such limitations on experimental flexibility apply generally to any studies conducted in a factory environment during normal commercial practice.

**Small scale production: Temperature measurement and monitoring**

*Research design - methods and procedures*

Raw material

Three kilograms of raw mung and lupin seeds were measured into standard containers and soaked for eight hours. The excess water was drained away and the soaked seeds were left undisturbed for a further four hours before spreading evenly
over the sprouting trays. The sprouting trays were placed in the growing chamber so as to counterbalance any differences in growing conditions caused by location within the chamber (Figure 9).

![Diagram of sprouting trays and probes](image)

Figure 9. Floor arrangement of sprouting trays and position of probes.

**Data collection**

Two temperature probes were located in identical positions within the lupin and mung sprout masses. Room temperature and humidity probes were mounted immediately alongside the sprouting chamber used in the experiments.

The temperature data were collected automatically using a Squirrel data logger (Model 1200 series 12 bit, 1983). This device samples all inputs at user set intervals, and stores the readings and the time of recording in solid state memory. The Squirrel data logger can record up to 13 channels and can measure voltage and pulse rate in addition to temperature and humidity. Four probes were used in this study. The readings are downloaded onto a computer and the data files were translated in Lotus format. The results are usually presented in graphic format. Reading were taken every 15 minutes for up to five days.
Figure 10. Temperature records small scale production
Figure 11. Temperature records small scale production
Figure 12. Incidence of missed watering cycle
Results and discussion

Chamber room temperature

As shown in Figure 10, there were some changes in room temperature readings, but these were independent of changes taking place in the external environment. This suggests that the chamber was adequately insulated from outside influences. It also indicates that the high summer crop failures as reported by management, may have been caused by factors other than high summer temperatures.

Some of the changes in room temperature appear to be related to heat which was generated by the sprout masses. As would be expected, irrigation of the sprouts had an immediate effect upon the temperature of the sprout masses and, as can be seen in Figure 10, there is a strong relationship between changes in room temperature and changes in sprout mass temperature because of watering patterns. The introduction of ventilation fans would probably reduce the extent of room temperature variations.

Sprout mass temperatures

There is a number of differences between the sprout mass temperatures of mung and lupin (Figures 10 and 11).

- A change in temperature is observed earlier in the mung sprout mass than in lupins. This is probably caused by the thick, hard seed coat of lupin impeding imbibition, and delaying the commencement of the sprouting process.

- From day 3, the sprout mass temperature of lupin rises more quickly than that of mung (Figure 10) indicating that lupin germination probably involves a higher metabolic rate. Such rises in the sprout mass temperature of lupins may result in the creation of conditions conducive to microbiological contamination. This could cause a serious problem under the full scale production runs of 100 kg which JAS uses to grow mung sprouts. One of the research limitations was that
single seeds could not be used to determine relative heat loss and metabolic rate in the commercial environment.

- Sprout mass temperature increases seen in mung and lupin are arrested by irrigation by water (Figure 10 and 11). This has the dual effect of providing moisture for both growth and cooling. As both factors are essential for acceptable sprout quality, the type and method of watering system used by JAS has a large bearing upon product quality.

- The importance of the watering cycle on sprout quality can be seen in Figure 12. When one watering run was missed, there was a rapid rise in temperature. This peaked at 25°C in the mung sprout mass during the next four hour period before the next watering cycle. The temperature in the lupin sprout mass rose to above 25°C before the next watering and continued to rise throughout the time period. This batch of lupin sprouts was heavily contaminated while the mung batch was still of acceptable quality.

- As there are differences in growing characteristics between mung and lupin, the successful growing of lupin sprouts will probably require a significant modification of the normal JAS watering system.

- The temperature of the water used for irrigation is a factor which will have an influence on sprouting potential. The irrigation water used by JAS is at normal tap temperature (18°C). This means that, during the early stages of germination, the irrigation water will be about the same as the sprouting mass temperature while, at the later stages of sprouting, it will be lower than the sprout mass temperature. Better control over sprout mass temperatures could be achieved by using chilled water. Unfortunately, the prohibitive increase in costs this would engender make this an uneconomic option for JAS.
Conclusion

There are marked differences between the processes of sprouting lupin and mung. The same environmental conditions are not likely to be suitable for growing both types of sprouts. Lupin is particularly sensitive to rapid increases in sprout mass temperature which result in sprouts of unacceptable quality.

The higher temperature generated in the lupin sprout mass compared with mung, suggests a higher metabolic rate. The temperatures would be expected to rise much higher with a commercial run. It is clear that the optimal conditions for sprouting must be different for lupin and mung. Further research is recommended to determine these conditions.

As the temperature increased in the mass of sprouting lupins, a foul odour was detected. Colour examination revealed a slimy brown mass on the sprouts in the bottom half of the chamber. This was caused by microbial damage.

Small scale production: Microbiological testing

Multitudes of microscopic living organisms are present on all food; most are harmless, while some cause spoilage and some are toxic. Few raw materials are free of such contamination. Farm crops attract a wide variety of soil, dust and water-borne organisms. Processing of such raw material inevitably spreads contamination. The initial contamination of foods may not be high but, if the food source that they contaminate can supply them with the necessary nutrients for growth and reproduction, the micro-organisms will rapidly grow. Temperature and time are important for the growth and reproduction of micro-organisms which reproduce and grow best between 15°C and 48°C. This is the ‘danger zone’ for food (Figure 13 - Food spoilage temperatures). The longer food is kept between these temperature, the greater is the risk of microbial contamination. This may alter the food nutrient content, freshness and palatability of the product. Often the micro-organisms and the toxins they produce when ingested in high quantities, cause food poisoning (Tortora, Funke and Case 1989, p. 698).
Figure 13. Food spoilage temperatures.
Source: (Tortura, Funke and Case 1989, p. 696).

Rationale for microbiological testing

The principle of hygienic practices in the food industry is to encourage procedures designed to eliminate the occurrence of pathogenic bacteria or other micro-organisms and/or regulate the occurrence of non-pathogenic bacteria which make food harmful or unsuitable for human consumption.

Throughout the food industry, it is the manufacturer’s responsibility to prevent the spread and growth of micro-organisms to the best of their ability, by careful hygiene and temperature control routines (Food Manufacture 1993, p. 25)

It is important that food produced in a commercial environment be safe for human consumption. The principal objectives of microbiology testing, as suggested by Hayes (1992), are to ensure that the food meets certain statutory standards. These standards are normally listed by government approved authorities, and can vary from
one state to another within a country and between countries. The regulations may be internationally agreed upon for most pathogenic and disease causing organisms.

Another objective of microbiological testing is to ensure that the food meets the internal standard set by the processing company or the external standards required by the purchaser.

It is important to ensure that the food material entering the factory for processing be of the required standard and/or meet a standard agreed with a supplier. It is necessary to start with raw materials having a minimal level of contamination so that the final product similarly has a minimal or safe bacterial or microbial count.

The final objective of microbiological testing is to ensure that process control and line sanitation are maintained. This restricts or discourages the multiplication of micro-organisms (Hayes 1992, p. 140).

Possible contamination points

Sprouts are grown hydroponically at warm temperatures ranging from 20°C to 24°C with 100 per cent humidity. There would be many species of bacteria and mould which would thrive within this range of temperature and humidity unless proper hygienic conditions are exercised during growth and harvesting. Proper care has to be taken after harvest and during storage to avoid cross contamination. The following flow diagram (Figure 14) shows the possible contamination points in the commercial production of sprouts.
Food spoilage

There are six major groups of micro-organisms recognized by Hayes (1992). These are bacteria, fungi, viruses, algae, protozoa and rickettsias. The bacteria are the most important in relation to food, but fungi can also have a significant role.
Bacteria are the most ubiquitous of living organisms and are present on everything and are everywhere (Hayes 1992, p. 1). Although some species of bacteria are 'human friendly', others can be hazardous. Some bacteria flourish at 0°C and others up to 100°C, but none can flourish under both extremes. This adaptability of bacteria often causes unexpected problems in the food industry though the problems could be minimized by controlling environmental factors favourable to the acceleration of microbial growth (Hayes 1992, p. 1).

For food industry purposes it is convenient to classify bacteria as pathogenic or non-pathogenic.

Pathogenic bacteria

Pathogenic bacteria are those which are harmful to humans. These include:

Salmonella

The genus Salmonella contains nearly 2000 different species and strains. Almost all members of this genus are potentially pathogenic and have been causative organisms in food poisoning (Hayes 1992, p. 8; Tortora et al. 1989, p. 266). Salmonellae are commonly transmitted to humans via foods of animal origin. On rare occasions plant materials are the vectors (Christian 1989, p. 23).

During the period March-April 1988, 143 cases of Salmonella saint-paul and 16 of Salmonella virchow PT34 infections were associated with the consumption of sprouted imported mung beans in England (Brown and Oscroft 1989, p. 1).

Salmonella contamination in mung beans imported into England was traced to possible cross-contamination from dust derived from an animal feed mill (Mahony, Cowden et al. cited by Brown and Oscroft 1989, p. 1). In 1988, a widespread outbreak involving 148 cases and three different strains (Salmonella saint-paul, Salmonella muenchen and Salmonella havana) was reported in Sweden. The
Swedish Department of Health and Social Securities advised the public to boil bean sprouts for at least 15 seconds before eating (Brown and Oscroft 1989, p. 1).

Outbreaks of salmonellosis in both the United Kingdom and Sweden in 1988, were traced to sprouts produced from Australian mung beans. At the height of the outbreak, the main British importer held stock, presumed to be contaminated, worth $300,000 (Christian 1989, p. 23).

*Salmonella* can survive for long periods in or on dry seed and multiply rapidly on hydration which is necessary to promote germination and production of bean sprouts. *Salmonellae* are difficult to isolate from mung beans before germination. Since mung bean is a significant import item, the Department of Primary Industry and Energy of the United Kingdom developed a Code of Practice to control contamination of beans from *Salmonella* which apparently comes from the harvesting and handling environment (Christian 1989, p. 23).

The Campden Food and Drink Research Association has developed guidelines which proposed the limits for *Salmonella* testing (Table 8). These guidelines should be used for both the frequency and type of tests to be performed. They should not be used as a standard for acceptance and rejection of any production of batch (Brown and Oscroft 1989, p. 13).

### Table 8. *Salmonella* testing: Suggested limits

<table>
<thead>
<tr>
<th>Sample</th>
<th>Suggested frequency of tests (minimum)</th>
<th>Suggested sample size</th>
<th>Suggested limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried beans</td>
<td>20 x 15g samples per consignment</td>
<td>20 x 25g</td>
<td>Absent in 25g</td>
</tr>
<tr>
<td>Final product</td>
<td>2 samples/day/production line</td>
<td>25g</td>
<td>Absent in 25g</td>
</tr>
</tbody>
</table>


To identify the presence of pathogenic bacteria, a more sensitive method of evaluation is required than the colony counting method. This is because a very small number of organisms within a population can cause health problems so that a very demanding microbiological standard is required. One alternative method of
evaluation does not count actual bacteria numbers, but reports whether growth has taken place from a certain size of sample. For example, *Salmonella* present in 25 g means that a sample of 25 g of sprouts or food was sampled and subjected to tests for that organism. The result would be the same whether one or millions of cells were originally present. A positive response to the tests would be sufficient to show that the sampled batch is unfit for consumption (Food Manufacture 1993, p. 25).

*Salmonella* testing is done to ensure that the risk of the presence of *Salmonella* is minimized. If *Salmonella* is isolated, then the appropriate course of action detailed in the Company’s Quality Assurance Manual should be followed (Brown and Oscroft 1989, p. 13).

*Escherichia coli*

There is only one species in the genus *Escherichia*, *Escherichia coli* (Hayes 1992, p. 8).

*E. coli* is not usually considered to be pathogenic. However, it can be a common cause of urinary tract infections and certain strains produce enterotoxins that commonly cause traveller’s diarrhoea (Tortora *et al.* 1989, p. 266).

*Escherichia coli* tests are designed to ensure that the contamination of the final product is within the suggested limits (Brown and Oscroft 1989, p. 14). The suggested frequency of testing for *E. coli* is at least five samples of raw seed per consignment and two samples/day/production line of sprouts. In a 20 g sample, the *E. coli* count should be < 10 per gram for the raw seeds. However, the count for final product (sprouts) should be < 1000 per gram (Brown and Oscroft 1989, p. 13).

A survey was conducted in 1992 by the Health Department of Western Australia, and 75 local authorities, in metropolitan and country areas, on salads for sale to the Western Australian public. The premises where salads were collected (manufacturers and retailers) were grouped into two categories, good hygiene and poor hygiene. Bacterial assessment of salads from these premises was made using
the *E. coli* count as an indication of contamination through poor personal hygiene, and from cross-contamination from the other foods. The results show that there was no correlation between the hygiene rating of the premises and product collected from retail and manufacturing premises (Western Australian Food Monitoring Program 1992, p. 15).

**Non-pathogenic bacteria**

Though non-pathogenic bacteria are not harmful, they should not be allowed to grow on food used for human consumption. If their activity increases beyond a safe limit, food may spoil, "go off" or change significantly in appearance, texture, and flavour. For example, *Erwinia* species are primarily plant pathogens which can cause plant soft rot diseases. These species produce enzymes that hydrolyse the pectin between individual plant cells and thus cause the plants to rot (Tortora *et al.* 1989, p. 267). The genus *Xanthomonas* is similar to *Erwinia* and produces soft rot in plants. This can cause great losses in quality of produce for horticulturists and farmers (Frobisher, Hinsdill, Crabtree, and Goodheart 1974, p. 472).

Pseudomonads are very common and are no threat to the health of individuals. These microorganisms can grow at refrigeration temperatures and impart an off taste and colour to food (Tortora *et al.* 1989, p. 264).

Pseudomonads (Genus *Pseudomonas*) are unusually resistant to chemical activity and may even grow in some disinfectants and antiseptics. They do not ordinarily cause disease, but can become pathogenic in the absence of normal competitive microflora. When a strong antibiotic is used to clean surfaces, the growth of other microbes is suppressed, but this does not adversely affect the stubborn "opportunistic pathogen" the pseudomonads. This behaviour has made these common and normally harmless bacteria very troublesome in hospitals. In the food processing industry, the pseudomonads are normally harmless as there are competitive microflora present in the environment (Tortora *et al.* 1989, p. 172).
It is important for JAS staff to monitor the growth of non pathogenic as well as pathogenic bacteria. The standards set by the Campden Food and Drink Research Association on the pathogenic and total aerobic count could be used as a benchmark for testing the production of mung and lupin sprouts grown in the commercial environment at JAS. The Western Australian Food Standard Regulations do not include a microbiological standard specifically for salads. The Western Australian Food Monitoring Program 1992, has derived a general guideline for ready to eat food-processed foods to determine the microbiological quality of salads. This guideline is also used to determine the degree of bacterial contamination in the mung and lupin sprouts produced in the JAS environment.

**Data collections: Methods and procedures**

Duplicate samples of mung and lupin seeds and sprouts were collected in clean freezer bags and labelled. Sprouts were picked up after harvest and washing, when they were ready for retail distribution. The bags were sealed immediately and stored in a freezer (D.S. Petterson and P. Wood personal communication).

**Testing for pathogenic bacteria**

Sets of samples were sent to the microbiology laboratory, Division of Animal Industries, Department of Agriculture, Western Australia, to test for the presence of *Salmonellae* and *Coliforms*.

**Testing for non pathogenic bacteria**

*Preparation of samples for microbiological testing*

Twenty seedlings were picked at random from the sample bag. Each seedling was cut length-wise into three pieces; tops, shoot, root (Table 9). This was done to determine if any one part had an excess microbial loading. It is not known if the bacteria responsible for sprout smell or rot are present on the surface or inside the tissues (P. Wood, personal communication, February 1993). As it was thought that
micro-flora could be present on the external surface of sprouts, only surface washes were used in further testing. This was a deviation from the normal procedure wherein all the samples should be chopped and homogenised before washing. The gram stain technique was used to broadly determine the bacteria categories (Appendix 1).

Table 9. List of samples tested

<table>
<thead>
<tr>
<th>Raw lupin seeds</th>
<th>Raw mung seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lupin sprout seed</td>
<td>Mung sprout seed</td>
</tr>
<tr>
<td>Lupin sprout shoot</td>
<td>Mung sprout shoot</td>
</tr>
<tr>
<td>Lupin sprout root</td>
<td>Mung sprout root</td>
</tr>
</tbody>
</table>

**Procedure**

1. Each sample was placed in a sterile Petri dish.

2. 50 mL of sterile water was pipetted on to the sample which was shaken gently for two minutes.

3. 5 mL of this wash was pipetted out and stored in a sterile bottle and frozen, an acceptable technique for the storage of samples used by the Department of Agriculture, Western Australia. This procedure was repeated for all the samples.

Although some micro-organisms are killed by freezing, about 50 per cent may survive. Moreover, bacterial spores are unaffected by freezing (Hayes 1992, p. 128). It is to be expected that the frozen samples of wash would contain some representative micro-organisms for growing on culture plates.

**Preparation of dilutions**

Samples were thawed for four hours before preparing dilutions of 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6}. The procedure is shown in Figure 15.
Testing the samples

One set of samples was sent to the Pathogenic Bacterium Testing Laboratory of the Department of Agriculture, Western Australia, to test for the presence of *Salmonella*.

Tests for non-pathogenic bacteria were conducted in the Plant Pathology Laboratory of the Department under the guidance and supervision of Dr Peter Wood, Plant Pathologist.

Sprouts were tested for two major bacterial groups:

1. The fluorescent pseudomonads

2. The *Erwinia*
A suitable culture media is required in which to grow these organisms. Tortora et al. (1989) proposed principles upon which a selection of a suitable culture media could be made. The medium must contain the right nutrients for the particular micro-organism to be grown. It should contain sufficient moisture and oxygen and be properly adjusted for pH. The medium must be initially sterile so that only the organisms added to the medium should grow. The growing culture should be incubated at the proper temperature (Tortora et al. 1989, p. 152).

The media selected for this study were:

1. The fluorescent pseudomonads: The preferred medium for the isolation of pseudomonads is Kings B medium (Lelliott and Stead 1987, p. 176-177).

The composition of the Kings B medium is:

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difco protease peptone</td>
<td>20 g</td>
</tr>
<tr>
<td>Glycerol (AR Grade)</td>
<td>10 g</td>
</tr>
<tr>
<td>K₂HPO₄ anhydrous</td>
<td>1.5 g</td>
</tr>
<tr>
<td>MgSO₄·7H₂O</td>
<td>1.5 g</td>
</tr>
<tr>
<td>Agar</td>
<td>15 g</td>
</tr>
</tbody>
</table>

The pH is adjusted to 7.2 with the addition of a few drops of 40 per cent NaOH.

2. The xanthomonads: The preferred medium for the isolation and growth of xanthomonas is a non selective medium known as SPA (sucrose peptone agar). The composition of the SPA medium is:

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>20.0 g/L</td>
</tr>
<tr>
<td>Peptone</td>
<td>5.0 g/L</td>
</tr>
<tr>
<td>K₂HPO₄</td>
<td>0.5 g/L</td>
</tr>
<tr>
<td>MgSO₄·7H₂O</td>
<td>0.25 g/L</td>
</tr>
<tr>
<td>Agar</td>
<td>15.0 g/L</td>
</tr>
</tbody>
</table>

Adjust pH to 7.2-7.4 using 40 per cent NaOH.

3. The *Eriwinia* bacterium: The selected medium for *Erwinia* is CVP (crystal violet pectate). The composition of the medium per 500 mL was:

(a) 1.0 mL 0.075 per cent (w/v) crystal violet solution

(b) 4.5 mL 1N NaOH (4 g/100 mL)

(c) 3.0 mL 10 per cent CaCl$_2$ H$_2$O (10 g/100 mL)

(d) 2.5 g DIFCO Agar

(e) 1.0 g NaN$_3$

(f) 10 g sodium polypectate

(g) 0.5 mL 10 per cent sodium lauryl sulphate (5 g/50 mL)

(Reference: Lelliott and Stead 1987, p. 179).

The dilutions (in triplicate) were put on the prepared plates by the spread method (see Appendix 5).

The culture was left to grow for 24 h in an incubator at 24°C.

The plates were incubated at 24°C for 24 hours and then counted.

**Observations on the culture medium**

The observation on the Kings B medium for Pseudomonads was done under ultraviolet light where the Pseudomonads are fluorescent.

The observations were recorded and are presented in Appendices 2 to 4.

On the SPA medium, white colonies, yellow colonies and mixed colonies were counted and recorded. The Streak plate method of isolation was used to obtain pure cultures (see Appendix 5). On the CVP medium, pitting was observed which was caused by *Eriinia*. Colonies were counted and recorded.
Results and discussion of microbiological testing (small scale production)

The samples were tested for pathogenic and non-pathogenic bacteria using the methods described above.

Results of pathogenic bacteria testing

None of the samples was found to contain *Salmonella* or *E. coli* which suggests that the growing environment conditions were hygienically satisfactory.

Results of non-pathogenic bacteria testing

*Pseudomonas fluorescens*

The sprouted mung seeds, sprouted lupin seeds and lupin shoots were all found to be contaminated with *Pseudomonas fluorescens*. This occurs as a saprophyte and may not cause any serious problems when growing on the sprouts (P. Wood, personal communication 1993).

Pseudomonads are very common in the natural environment and are no threat to the health of individuals. Many pseudomonads can grow at refrigeration temperatures and impart off tastes and colours to foods (Tortora *et al.* 1989, p. 264). No cleaning can readily eliminate the presence of pseudomonads as they are unusually resistant to chemical activity and will even grow in some disinfectants and antiseptics (Tortora *et al.* 1989, p. 172). This survival and growth of *Pseudomonas* may be responsible for changes of sprout appearance and taste even when they are refrigerated.

*Erwinia* spp.

Mung shoots, lupin seeds and lupin shoots were found to contain *Erwinia* spp. The genus *Erwinia* can occur as a primary pathogen or as a storage organism and is commonly involved in the spoilage of vegetables (P. Wood, personal communication 1993; Hayes 1992, p. 9). Further work is required to establish the source of *Erwinia* infection in the JAS samples. It may be present as a contaminant of the seed surface,
or it may occur within the tissue of the seed. The implications are that it can contaminate water and other hard surfaces within the growing area. It thus becomes necessary to follow thorough cleaning routines and to disinfect all surfaces before use.

Infection in the lupin seed sample suggests that the seed might have had an excess microbial loading. This is valuable evidence as it suggests that lupin needs an extra treatment to grow quality sprouts. Examples of such treatment include more chlorine in the irrigation water than mung, extra care in washing of seeds, and the use of a surface decontaminant. If micro-organisms in the seed tissue are also likely to infect seed then more research will be required by the lupin breeders to develop appropriate varieties.

Conclusion

The microbial activity on the sprouts is a result of the cumulative effect of seed quality, water (frequency and amount), and environmental conditions. Since there are no serious problems with the mung sprouts, it is assumed that the environment is reasonably satisfactory to grow lupin sprouts. The problem of foul smell in lupin sprouts is expected to become aggravated when a commercial batch is tried.

Further, it is important that, for lupin to be a substitute or an alternative to mung, it must perform in an equivalent manner to the product characteristics of mung such as length, weight, and appearance.

Small scale production experiment-physical characteristics and appearance of mung and lupin sprouts

Introduction

In the determination as to whether lupin sprouts are likely to be substitutes for mung or are quite different products, it is important to compare the physical characteristics
of the two. This includes general appearance, growth and development, length and weight gain during sprouting, and consumer acceptance of the sprouts.

Senior staff of JAS, consider that a ‘good quality’ mung sprout would be about 8 to 10 cm long with an even shoot thickness, with none or very little root-thread like structure in the tail. There would be no root hair, green leaves or seed coat. The sprout should mainly be white. If the lupin sprout is to be marketed as a direct substitute for mung sprouts then it would be expected that the two sprouts should be physically identical or very similar (JAS management, personal communication, December 1992).

The results of measuring changes in sprout length and weight during various stages of sprouting are now considered as are the effects of the different types of seed coat of the sprouted lupin and mung.

*Preparation of raw seeds*

Three kilograms each of raw lupin and mung seeds were measured into standard containers and soaked for eight hours. The excess water was drained away and the soaked seeds were left undisturbed for a further four hours before spreading evenly over the sprouting trays. The sprouting trays were placed in the growing chamber so that conditions were identical for both the sprouts (Figure 9).

*Physical appearance: Sprout length during germination*

*Method - sampling*

Matched samples of lupin and mung sprouts were chosen from identical locations in the sprouting trays at day 4, day 5 and day 6 of sprouting.

*Data collection*

Each sample selected was measured and photographed under standard conditions.
Mung sprout manufacturers face a problem of having too long a root on the sprouts which adversely effects the appearance. Because of this a change in the harvesting procedure was tried. Instead of picking by gently holding the sprouts and removing them with an upward and away motion from the tray, the sprouts were snapped by gently holding them and sliding them slowly sideways on the base of the sprouting tray to cut off the extra length of root. The base of the small scale production sprouting trays had a wire mesh similar in size that used in a fly screen. The procedure did not work for mung sprouts as the roots were very fine and slipped through the mesh while snapping. Lupin appearance was improved considerably by snapping although the loss in length would mean loss of weight in the final product.

Results and discussion

Appearance and length of sprouts

Mung and lupin sprouts develop quite differently. The lupin sprout develops much earlier and has achieved about 80 per cent of its final length by day 4 while the mung sprout has achieved only 50 per cent. The lupin sprout shoot takes up a higher percentage of its length while the mung sprout has a longer tail (or root). After day 6 sprouting, the average mung sprout is longer than lupin, but there is virtually no difference between them with regard to the quantity of edible shoot.

The comparative lengths of mung and lupin are shown in the Table 10.

Table 10. Comparison of length, percentage of shoot and root.

<table>
<thead>
<tr>
<th></th>
<th>Mung</th>
<th>Lupin picked¹</th>
<th>Lupin snapped²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length in cm</td>
<td>Shoot %</td>
<td>Root %</td>
</tr>
<tr>
<td>Day 4</td>
<td>10.9</td>
<td>36.5</td>
<td>63.5</td>
</tr>
<tr>
<td>Day 5</td>
<td>15.3</td>
<td>46.8</td>
<td>53.2</td>
</tr>
<tr>
<td>Day 6</td>
<td>20.2</td>
<td>55.1</td>
<td>44.9</td>
</tr>
</tbody>
</table>

Note: Two different methods of harvesting: Picking and snapping are defined as follows.
1. Picking. Gently holding the sprouts and removing them with an upward motion away from the tray
2. Snapping. Gently holding sprouts and sliding them slowly sideways on the base of the sprouting tray to cut off the extra length of roots.
Graphic presentation of comparative length of mung and lupin is shown in Figure 16.

![Figure 16. Comparison of length of sprouts at different ages - cm.](image)

**Note**
1. **Picking.** Gently holding the sprouts and removing them with an upward motion away from the tray.
2. **Snapping.** Gently holding sprouts and sliding them slowly sideways on the base of the sprouting tray to cut off the extra length of roots.

The results reported in Table 10 and shown in Figure 16 indicate that there are considerable differences in the length of mung and lupin spouts during the sprouting period.

The lupin sprouts are much longer than are mung sprouts at day 4, but this advantage in yield (weight gain) has disappeared by day 6. As both sprouts were grown under identical commercial conditions, the research data shows that the apparent advantage in 'value-adding' attributed by other researchers (Yu et al. 1985 and Yates 1992) to lupin sprouts, only applies to the early stages of sprouting. As mung are usually harvested at between five and a half to six days, any commercial advantage in using lupin would only be attained by harvesting lupin at day 4. This would yield a sprout of similar shoot and root length as the day 5 mung and could have an added
advantage of a longer post-harvest retail shelf life. It was noticeable that the lupin sprout has a proportionally shorter root than the mung sprout, and so should better meet the criterion of a ‘good sprout’.

This means that lupin sprouts could be harvested as early as day 4 as the additional length gain is relatively small thereafter. Mung should be left to about day 5 before harvesting, as it is a much later sprouter.

At the suggestion of JAS staff, the lupin sprout was also ‘snap harvested’ by removing the extended root. This produced a much shorter root and a more appealing sprout, but it had the effect of eliminating any ‘value-added’ commercial advantage over the mung sprout. The snap harvest procedure did not work for mung as the mung roots were too fine. ‘Snap harvesting’ of lupin sprouts appears to have little merit. This method would result in a large loss in weight and sprouts are currently sold by weight.

The results indicate that mung and lupin are comparable in terms of value-adding, but that lupin sprouts can be harvested earlier and may have a longer post-harvest shelf life than mung sprouts.

**Physical appearance: sprout weight/yield during germination**

If lupin sprouts are to be regarded as a suitable commercial replacement or alternative to mung sprouts, then it is important to compare their growing characteristics and weight gains.

Yu et al. (1985, p. 177) found that while mung seeds made a five-fold gain in weight during the sprouting process, the weight of lupin increased 7.5 times during the same period. Lupin sprouts were also found to be superior in quality than mung or soy sprouts. From the processor’s point of view, lupin should be a superior product as regards value-adding. With good quality mung seeds, the raw weight increases eight to ten times with sprouting in the JAS factory (W. Ming, personal communication 1993) which is better than reported laboratory values. As commercial conditions
improve the weight of mung by sprouting, then likewise, lupin should also show an appropriate increase in weight gain. It is likely that growing conditions will have a marked influence upon the physical characteristics of the end product.

The weight gain of mung and lupin were tested by the following means.

Methods

Sampling

Matched samples of lupin and mung sprouts were chosen from identical locations in the sprouting trays at day 4, day 5 and day 6 of sprouting.

Data collection

Each sample selected was:

1. measured and photographed under standard conditions;
2. weighed on two separate electronic balances and the weight averaged.

The growing sprouts were weighed at days 4, 5 and 6 and the weight achieved at each growth stage was compared with the weight of raw seeds. Results are presented in graphic form.

Results and discussion

Weight gain of sprouts

The weight of mung seeds grown under commercial conditions increased 8.4-fold by day 4 and 9.2 times by day 5. The weight of lupin seed grown under the same commercial conditions increased by 6.8-fold and 7.7 times respectively (Figure 17).

Figure 17 shows the relative growth of lupin and mung on different days.
Figure 17. Relative growth of lupin and mung compared with seed weight - grams.

Note
1. Picking. Gently holding the sprouts and removing them with an upward motion away from the tray.
2. Snapping. Gently holding sprouts and sliding them slowly sideways on the base of the sprouting tray to cut off the extra length of roots.

Figure 18. Comparison of weight increase of sprouts in grams compared with the original seed weight (times weight) (small scale production).

Under the test conditions mung grew more in times weight than did lupin during sprouting (Figure 18). These results differ from those of Yu et al. (1985, p. 177) who
found that the lupin sprout had 7.5 fold and mung a 5 fold increase in weight after five days. Yu’s results suggest that by weight gain alone, lupin has an advantage over mung.

In this experiment, lupin gained more weight (14.3 per cent) between days 4 and day 5 whereas mung has its better weight gain (28.3 per cent) between day 5 and 6 (Table 11). This explains why the commercial processor harvests mung sprouts at five and a half days or six days. Though the weight gain of lupin on day 6 was impressive the sprouts looked over grown. Indeed the weight gain by day 6 might not be sufficient to compensate for a loss in quality and the cost of an extra day of using the facilities (opportunity cost). It is expected that lupin harvested on day 4 would have an advantage over mung in shelf life and opportunity cost.

While snapping improved the appearance considerably on day 5, loss in weight from the picked lupin was 10.4 per cent. This would make the snapped lupin slightly more costly. No firm information is available concerning the attitudes of consumers towards the presence of long roots on the sprouts purchased.

Table 11. Percentage of growth over previous day (increase in weight)

<table>
<thead>
<tr>
<th></th>
<th>Day 0-Day 4</th>
<th>Day 4-Day 5</th>
<th>Day 5-Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mung</td>
<td>740.0%</td>
<td>9.5%</td>
<td>28.3%</td>
</tr>
<tr>
<td>Lupin picked¹</td>
<td>576.7%</td>
<td>14.3%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Lupin snapped²</td>
<td>506.7%</td>
<td>13.2%</td>
<td>13.6%</td>
</tr>
</tbody>
</table>

Note: Weight of raw seed - Mung = 0.05 grams - Lupin = 0.15 grams

1. Picking. Gently holding the sprouts and removing them with an upward motion away from the tray.
2. Snapping. Gently holding sprouts and sliding them slowly sideways on the base of the sprouting tray to cut off the extra length of roots.

Mung and lupin sprouts add value to the dry seed, but the extent of weight increase is dependent upon the environmental conditions and seed variety. These results do not indicate that lupin automatically or consistently offers a higher yield than mung beans when both are grown under the same conditions as operates at the JAS factory.
This means that if lupin sprouts are to be grown commercially at JAS then different growing conditions will need to be created.

**Physical appearance: seed coat count**

There are marked physical differences between the seed coats of raw lupin seeds and mung beans. As previously described, mung is a small seed (50 mg) with a relatively thin seed coat (12 per cent) while lupin is much larger (150 mg) and the seed coat (23 per cent) is both thicker and harder.

When comparing the effects of sprouting mung and lupin, it is necessary to consider whether the differences in seed coats have any implications on the acceptability of the end product by consumers.

During the germination process, the mung and lupin sprouts were washed by means of the equipment used by JAS to clean the mung sprouts. Of particular interest was whether the seed coats were detached by the washing process.

As can be seen in Figure 19, only a very small percentage of the mung bean seed coats remained attached to the sprout from day 4, while over 25 per cent of lupin seed coats were still securely attached to the growing sprout at that stage. It is clear that the lupin seed coats were more likely to remain attached by the time the end product was ready for commercial consumption.

This finding could have serious implications for the commercial potential of lupin sprouts. While no research data is available, it does seem that most consumers prefer to eat sprouts without any attached seed coats. If this is so, then there may be additional costs involved in removing the lupin seed coats.
Handling characteristics

One important characteristic of a quality sprout is that it should be durable and not overly sensitive to damage during handling. According to JAS staff, the mung sprout tends to be delicate and needs to be handled gently throughout the sprouting and post-harvest stages. Relatively, the lupin sprout is more robust and less likely to handling damage. This could be an important advantage in favour of lupin sprouts for the retailer.

Conclusions (small scale production)

The results show that the temperature of the lupin mass rises higher than the mung mass during sprouting. Lupin generates more heat presumably because of a higher metabolic rate. The temperatures would be expected to rise much higher in a commercial sized batch. This higher heat production and retention by lupin means that the commercial conditions for optimal sprouting of lupin must be different to these needed for mung. For example, the use of cooling water may need to be more frequent.

Lupin sprouts had a foul odour indicating microbial growth. Although the microbial activity may be as a result of cumulative effects of water (frequency and amount), temperature and quality of seed, the problem is expected to be aggravated when commercial sized batches are tried.
None of the samples were found to have any pathogenic bacteria. Lupin and mung sprouts showed a presence of bacteria from *Pseudomonas* and *Erwinia* species. Pseudomonads would be difficult to control as they could survive even under refrigerated conditions. The presence of *Erwinia* suggests that vigorous cleaning of the growing premises is an absolutely necessity.

These results show that, when mung and lupin sprouts are grown in small batches under identical conditions, lupin at day 4 is best in appearance, but by day 5 they have an advantage of maximum weight gain. Mung sprouts have most weight gain by day 5 or day 6 which is higher than lupin. On the basis of appearance, it seems that lupin could not be a direct substitute for mung. More research is needed before it can be concluded that lupin is acceptable to consumers of mung bean sprouts. It may be possible to promote lupin for different uses and a different market segment.

Mung in a pilot experiment gained ten times in weight, whereas lupin gained seven times. This results throws doubt upon previous work that lupin has a greater potential to add-value by producing a higher yield than mung sprout. Moreover, there is wastage expected in a commercial sized batch which might further bring down the added value of lupins.

Mung sprouts are harvested on day 6 in a normal commercial process. By appearance, length and weight, lupin is best harvested on day 5. There seems to be no advantage in growing lupin for one extra day. This could give lupin sprouts an advantage of an extra day of post-harvest shelf life. This could also mean that with the same facilities, the manufacturer could grow more batches of lupin than mung. For example, if the manufacturer was growing five batches of mung per month then, in similar conditions, six lupin batches could be grown.

Mung sprouts have a negligible number of attached seed coats by day 6, whereas lupin still has a significant number of seed coats attached. It may be possible that the extra seed coats of lupin may be washed off using the commercial process used for washing mung. This involves gentle agitation of the sprouts. If the same washing
system does not work, then there may be an extra cost for the manufacturer to either install a suitable washing system or to employ extra manual labour. Both alternatives would eventually increase the cost of lupin sprouts.

Upon completion of the small scale experiments, a series of measurements were taken of the relative performance of mung and lupin sprouts grown under normal commercial conditions.

While the small scale production runs used in the preliminary stages of the project provided valuable information about the relative characteristics of mung and lupin sprouts grown under commercial conditions, it would be unwise to automatically extrapolate those findings to a full scale production run.

**Full scale commercial production experiment: initial trial**

Discussions with JAS staff, together with observations of the production process, indicated that the vast amount of sprouted material resulting from the germination of 100 kg or more of raw mung seeds produced a growing environment which was vastly different to that created in the small pilot experiments.

For example, by day 5, the original 100 kg of raw mung seeds in a single growing chamber had increased in volume to a mass which exceeded one metre in height. The top layer was exposed to a completely different growing environment to that experienced in the lower layers. The water and oxygen supplies to the lower layers would differ greatly between the various layers and there will be marked differences in temperature readings in different parts of the batch. This, together with the differences in growing patterns observed in the small scale experiments, indicate that there should be an examination of the conditions within a large volume of lupin seeds used to produced sprouts in the standard commercial growing environment.
Preparation of raw seeds

The method used in the commercial preparation of mung seeds was used for preparing the lupin seeds.

Some 100 kg of raw seeds were taken and soaked for eight hours. The water was then drained away and the seeds left undisturbed for another four hours. The germinated seeds were then spread in growing chambers where they were grown with an intermittent supply of water for 5 to 6 days under dark conditions.

Methods

The full scale production process was observed daily and the following measurements were taken. The procedures used were identical to those used in the small scale production experiments.

1. Temperature measurements
2. Microbiological testing
3. Physical and appearance observations

Results

Observations showed that the first commercial scale production of lupin sprouts was unsuccessful because:

1. The sprouting mass grew to only about 60 cm. It was predicted on the basis of the small scale studies, that the mass would be taller than the standard mung sprout mass being grown in a neighbouring chamber which was about 100 cm. However, in the full scale experiment, lupin as shorter than mung.
2. The top (10 to 15 cm) layer of a full production run of mung sprouts is brown and dry because of lack of moisture and is discarded as unsuitable for commercial consumption. In this instance, the equivalent layer of lupin was
moist with an acceptable colour. This means that there is no need to discard the 10 to 12 cm top layer for lupin and this would lead to lower wastage.

3. The lower layers of mung sprouts are mostly of acceptable quality and are harvested for retail sale. The middle layer of lupin sprouts was slimy to the touch and produced a strong and unpleasant odour. The lowest layer was slimy and rotten and totally unacceptable for human consumption.

The lupin sprout mass was highly infected with microflora and these had penetrated the whole mass. The control batch of mung seeds which was germinated in an adjacent bay of the growing chamber at the same time was not affected by any contamination to this degree of severity.

The conclusion reached was that there was a need to conduct a thorough inquiry into the likely causes of the failure of the lupin crop. This could provide valuable information about the commercial growing of lupin sprouts.

There were a number of factors which could have contributed to the failure of this production scale batch of lupin sprouts.

1. **Power failure resulting in water restrictions**

When the full scale batch of lupin sprouts failed, enquires were made concerning any interruptions in the normal production cycle. It was found that, during the growing period, the ceiling of the sprouting room adjacent to the lupin chamber had collapsed. This resulted in an extended power failure and a cessation of the water supply for eight hours.

A consequence of this type of accident would be a rapid rise in the internal temperature of the growing mass. This would have accelerated the growth of microflora which grow exponentially once growth starts and favourable conditions exit. Yates 1992, (p. 16) found that the best sprout yield was achieved at 24°C and at higher temperatures than that which attracts microbial growth by day 3 of
sprouting. This batch of lupin sprouts had an extra strong off odour making them unfit for consumption.

2. **External contamination**

Because of the accident in the sprout room, contamination of the growing sprouts might have occurred. The area of breakage was close to the experimental area. Repairs involved traffic and other disturbances by repair and maintenance staff.

Microbial tests showed that the batch had no pathogenic bacteria present such as *Salmonella* and *E. coli*. However, it was infected with non pathogenic bacteria. Lupin and mung sprouts were infected with bacteria of the *Pseudomonas* and *Erwinia* species. Infection with *Erwinia* may have occurred from the dust spread during the repair of the false ceiling.

Physical appearance observations could not be done as the batch was heavily infected.

**Handling disadvantage**

The batch of mung which was in the same growing room was not infected to the same level as lupin. This implies that lupin is more sensitive to growing disturbances than mung. The handling advantage which was expected from work with small scale production tests disappeared.

**Conclusions**

The conditions suitable for growing mung did not appear optimum for growing lupin; at least in the size batches requested by JAS. However, as the results might be attributed to accidental circumstances, a further trial to test the suitability of lupins for sprout production was warranted.
Full scale commercial production experiment: final trial

The same procedure was used to grow another batch of lupin sprout which proved successful. The full scale production process was observed daily and measurements taken. Procedures adopted were as for the small scale experiments.

Methods

Measurements taken

1. Temperature
2. Microbiological testing
3. Physical and appearance observations

The standard method used in the commercial preparation of mung seed was used for preparing the lupin seed.

Temperature probes were inserted in two different locations in the same chamber containing lupin sprouts, and the results are as follows:

Results - temperature

Results of the commercial run are presented in Figure 20.
Figure 20. Temperature records; full scale production
Chamber room temperature

As shown in Figure 20, there were some changes in room temperature readings, but these were not related to diurnal or other temperature changes in the external environment. This shows that the chamber was adequately insulated from the external environment. The changes in room temperature appeared to be related to heat transferred from the sprout masses into the enclosed chamber. As expected, irrigation of the sprouts had an immediate effect upon the temperature of the sprout masses. Figure 20 shows that there is a strong relationship between changes in room temperature and changes in sprout mass temperature because of watering patterns.

Sprout mass temperatures

Changes in lupin mass temperatures are shown in Figure 20.

- Lupin mass temperatures often rose to a maximum of 30°C. Higher temperatures during lupin sprouting is an indicator that lupin generated more heat with sprouting than did mung.

- The temperatures rose much higher with the commercial size batch of 100 kg than it did in the pilot studies. Thus, conditions for optimal sprouting for lupin are different to those needed for mung especially with batches of commercial size. Further research is needed to determine these conditions.

- Sprout mass temperature increases seen in lupin (Figure 20) are arrested by irrigation with water. This has the dual effect of providing moisture for both growth and cooling. As both factors are essential for acceptable sprout quality, the type and method of watering system used by JAS may be more appropriate for mung. JAS may not be able to produce the best quality of lupin sprout under its present operating conditions. The limitation of the research in a commercially operating factory is that normal production must continue and it may not be possible to alter the room temperature or watering cycle for the purpose of growing lupin sprouts.
Microbiology testing

The standard for the levels of bacteria in sprouts are given in the The Campden Food Drink Research Association's technical manual. The 'Western Australian Food Monitoring Program' also provides an outline of standards expected for fresh processed salads in Western Australia. Both these standards were used as a basis for testing for pathogenic bacteria to determine if they were at acceptable levels. The testing for non-pathogenic bacteria was to determine if there were any basic differences between the two sprouts.

Methods

Procedures followed were similar to those used in the small scale experiment and the initial commercial scale production experiment.

Results - microbiological testing

Pathogenic bacteria

None of the samples (mung seeds, mung sprouts, lupin seeds and lupin sprouts) were found to contain *E. coli* or *Salmonella*. The presence of any of these organisms makes food pathogenic for human consumption. On the basis of total plate count, these observations confirm that the microbiological quality of the sprouts could be rated as 'good'. Table 12 presents the standards set by the 'Western Australian Food Monitoring Program' for sprouts.

<table>
<thead>
<tr>
<th>Table 12. Microbiological quality of salads as determined by the Total Plate Count (TPC) or <em>Escherichia coli</em> count (<em>E. coli</em> count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salad quality</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><em>E. coli</em> count (<em>E. coli</em>/g)</td>
</tr>
<tr>
<td>TPC (org/g)</td>
</tr>
</tbody>
</table>

On the basis of the count recorded and the above standard, the results of this research are seen in Table 13.

Table 13. Microbiological quality of lupin seed and sprout compared with mung seed and sprout as determined by the Total Plate Count (TPC) or *Escherichia coli* count (*E. coli* cou+)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Based on <em>E. coli</em> count</th>
<th>Based on total plate count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quality found</td>
<td>Quality found</td>
</tr>
<tr>
<td>Mung bean seeds</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Mung bean sprouts</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Lupin seeds</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Lupin sprouts</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

Note: Detail of count attached in Appendix 6.

The results confirm that both lupin and mung had no serious pathogenic problems. The seeds used were free of any pathogens. They also show that the sprout growing environment in JAS is sufficiently clean in not permitting growth of pathogenic bacteria. It needs to be noted that this observation is only for the tested batches and need not apply for production at all times. It is important that the batches in the production line be tested on a regular basis.

**Non pathogenic bacteria**

There are no microbiological standards outlined for non pathogenic bacteria in the Campden manual or by ‘the Western Australian Food Standards Regulation’. One possible reason for this is that these bacteria make food rot and produce a foul odour which is a self indicator that the food is unfit for consumption. The presence of these bacteria also reduces the shelf life of the food product. The effect of these bacteria require further investigation as it may show why lupin has more rot in commercial batches than mung.

Neither mung nor lupin contained any fluorescent *Pseudomonads* or *Erwinia* in any of the raw seed samples.
The sprouted mung seeds, sprouted lupin seeds and lupin shoots were all found to be contaminated with *Pseudomonas fluorescens* and Xanthomonads. Pseudomonads are very common in the natural environment and are generally no threat to the health of individuals.

Mung shoots, mung roots and lupin roots were found to contain *Erwinia* spp which are commonly associated with spoilage in vegetables. The intensity of the bacterial count disappears with dilution. A more vigorous cleaning routine within the growing area could be necessary to disinfect all surfaces before use. The bacterial counts were lower than those found in the small scale experiment and the initial commercial scale trial. This might mean that, because of the accident, JAS had changed a few fixtures and these new fixtures had few attached bacteria with which to infect new batches of growing sprouts. Unfortunately, the complete absence of infection may not be possible in a normal operating commercial system.

Observations showed that lupin root and mung root are more sensitive to *Erwinia* infection than other parts of the plant. The root starts getting brown and mushy in appearance much earlier than the infection shows on the shoots. The foul smell is stronger near the seed.

There was less infection in the lupin seed sample than in previous batches. Probably the earlier results were because of external infection and not because of infection in the seed tissue. There seemed to be more infections in the seeds where the seed coat was still attached (may be loose) to the seed. This provides a pocket in which the microbes may grow. Furthermore, the lupin seed coat does not disintegrate with the process of sprout maturation. The evidence shows that lupin seeds need an extra treatment to produce clean sprouts, such as more chlorine in the irrigation water than is required for mung, extra care in the washing of seeds and the use of a surface decontaminant. The mechanical removal of seed coats could improve the quality of lupin sprouts, but it is an extra cost to the manufacturer and could be a tedious task to perform.
Microbial activity is a reflection of the cumulative effect of all growing conditions. Excessive watering may aggravate if not accelerate the microbial count for lupin sprouts.

For lupin to be a substitute or an alternative to mung it must perform in an equivalent manner with regard to product characteristics such as length, weight, and appearance. This is especially so as there is not much difference in the microbial quality of the two products.

Appearance, length and weight of commercially grown lupin compared with mung

Lupin is whiter and the shoot of more even thickness than mung when grown under similar conditions. Figure 21 shows the comparison of length of sprout at different ages, during the commercial run. On day 4, the lupin sprout is longer than the mung sprout. On subsequent days, mung grows faster than lupin. On day 5, lupin was still longer than mung, but mung improved and was longer by day 6. The best harvest day for lupin on the basis of appearance and length is day 5.

Weight comparisons of sprouts in the commercial experiment are summarized in Figure 22. Lupin grows much slower after day 4 from germination. It could not be ascertained if this is a natural behaviour of lupin or if the growing environment conditions could improve growth rate. The weight gain in mung from day 5 to day 6 is significantly higher than that of lupin.
Mung Lupin picked

Figure 21. Comparison of length of sprout at different ages in the commercial experiment (November to December 1993).

Figure 22. Comparison of weight of sprout: commercial experiment
Seed coat

The lupin seed coat is thicker than that of mung and takes longer to loosen and shed from the cotyledons. Mung had only 1.5 per cent of the seed coat on seeds by day 4, whereas lupin had 26.5 per cent of seeds coats attached. The space between seed coat and cotyledons seems to hold microflora and provide a favourable environment for their growth.

Wastage rates

Height of the sprouting mass

The sprouting mass of lupin grew a little better in height in the commercial experiment (70 cm), but was still smaller than the mung (100 cm). The top layer of lupin was moist, whereas for mung it was dry. This implies that there is no need to throw away the few centimetres from the top of the lupin sprout crop.

The middle layer of lupin was not slimy to the touch, but had scattered patches of slimy rot and the slimy patches had a very strong foul odour. The sprouts did not appear as highly infected by microflora as they did in the first trial. They were tested for the presence of pathogenic and non-pathogenic bacteria. The appearance and thickness of the middle and bottom layers of mung was better than that of the top layer. Sprouts were of uniform thickness and whiter, although roots were thin with few root hairs. Compared with the lupin batch, only a few patches of mung roots were slimy and these were expected to be washed away in the washing process. In addition, the smell was less irritable.

The bottom layer of lupin sprouts was slimy and had smaller length sprouts.

The wastage rate remains the same in both the cases at about 20 per cent, and one layer of sprouts needed to be discarded in each case.
Washing and handling costs

The lupin sprouts with their thick seed coats, have a tendency to settle on the floor of the water tank while washing. The existing equipment at JAS is not adequate to handle the washing of lupin sprouts. Extra labour cost for washing could be needed which is estimated at about 25 per cent higher than that of mung. It could, however, be reduced by developing a suitable washing system for lupin sprouts.

Evaluation of the growing environment

Temperature control and heat generation

The control of room temperature at JAS seems to be satisfactory. However, it could be improved by providing sensor ventilation or cooling when the temperature rises above 24°C.

Sprout mass temperatures rose up to 30°C with commercial batches of 100 kg seeds and a 4.5 hour watering cycle. Temperatures could be reduced by watering more frequently or by using colder water. In either case, the quantity of water used at each watering should be just enough to make the sprouts moist, but not wet.

Reduction in the batch size would probably produce better quality sprouts. The small scale batches of lupin had temperatures rising up to 24°C. This is just the right temperature for producing sprouts. More work is required to optimize the batch size using the existing facilities at JAS.

Watering: amount and frequency

The four hourly watering interval appropriate for mung, was not suitable for lupin. Because of the seed size and seed coat characteristics of lupin, it holds more water and appears wetter than mung.

The amount of water applied was too much for lupin. Soon after watering the mung sprout mass appears moist, but did not hold water so as to appear wet, whereas the
lupin seems to hold extra moisture for a longer time. The extra moisture and temperature, higher than 24°C, provide favourable conditions for adverse microflora to grow.

**Batch size**

The existing batch size (100 kg of raw seed) is not appropriate for lupin sprouting. The heat generated and the excessive watering appears to favour microbial growth which affects the quality of the sprout. Part of the problem with batch size is because of the thicker seed coat of lupin. As the sprouts mature the seed coat either comes off or gets looser on the seed. In both the cases, the seed coat is still present in the sprout mass. This causes problems by holding or trapping water in the mass. The heat generated disintegrates the seed coat and all these cumulative effects provides favourable conditions for the growth of microflora. These then further infect the roots and shoots of the sprouts which turn brown, slimy and smelly. Because of the height of the growing sprout mass, there is physical pressure exerted by the sprouts of the top layer onto the sprouts in the bottom layer. Hence sprouts at the bottom were of poorer quality with excessive contamination than the sprouts of the top layer.

Problems with slimy seed coats did exist in the small scale experiment, but because the seeds were only in a few layers, the damage was not excessive. This implies that it may be advisable to grow lupin in smaller quantities or use more surface area to grow the same size of commercial batch. The appropriate batch size for lupin needs to be resolved. Another possible method could be the manual removal of seed coat during the process of growth. This may not be feasible because of the additional cost to the manufacturer.
Conclusions

*Full commercial experiment - final trial*

1. Mung beans gave about a six fold yield of sprouts after allowing for all wastage (discarding the top layer, seed coats and sprouts with poor health). Lupin yields about 5 times its weight in sprouts after allowing for all wastage.

2. As different frequencies and quantity of water are required for lupin than for mung, an independent watering system would be needed. Lupin might grow better with a variable water supply than with one fixed for the whole growing cycle. It might need more frequent watering (every two hours) on day 2 and day 3, and followed by four hourly watering for the rest of the cycle.

3. Better temperature controlled growing rooms with insulation, fans for ventilation, sensor lights for inspection, and an automatic door could improve sprout quality.

4. Commercial batches of lupin could be grown. More work on batch size is required to determine the optimum size.

5. Little change in the washing equipment may be needed. Lupin needs more agitation of water while washing to remove all the seed coats or a system wherein water is sprayed with a needle-like fine pressure spray, on the lupin to remove the remaining attached seed coats. An extra cost of 25 per cent is estimated for growing and washing lupins.
David Petterson, Senior Research Officer, Department of Agriculture, with Wu Ming, sprout grower, examining packaged 5 kg bags of lupin and mung sprouts ready for cool storage.

The Squirrel data logger used to measure the sprout mass temperature and the room temperature.
Washed mung sprouts ready for packaging

The washing channel showing mung sprouts
Arrange the seed trays within a sprouting chamber. Lupin seed yellow, mung seed green. Small scale experiment.

Lupin and mung sprouts ready for harvest.
Full scale experiment showing mung sprouts.

The watering system used in the growing chambers, full scale experiment.
Full sized batch of mung seed, 100kg.

Full sized batch of lupin seed, 100kg.
Growth rate of lupin sprouts as determined by length.

Growth rate of mung sprouts as determined by length.
Comparison of length of sprouts - Day 4.

Comparison of length of sprouts - Day 5.

Comparison of length of sprouts - Day 6.
CHAPTER 7

Cost analysis: lupin compared with mung

Introduction

Only a cost analysis provides accurate information on costs of production and profitability, and to do this the unit cost of producing lupin and mung sprouts was calculated. Prices of raw seed were at the rates prevailing in the wholesale market. Factory related costs and overheads are based on data provided by JAS. Appropriate assumptions were made where the information supplied fell short of the requirements of analysis.

While the cost analysis was limited in its extent, the comparisons derived provide sufficient indicators of economic viability of producing lupin sprouts to the potential investor.

Cost sheet

The cost sheet is presented in Table 14 and explanatory notes follow:
<table>
<thead>
<tr>
<th>Data</th>
<th>Lupin</th>
<th>Mung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selling price ($/kg)</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>Raw seed cost ($/tonne)</td>
<td>300.00</td>
<td>1,350.00</td>
</tr>
<tr>
<td>Yield of sprouts (times over raw seed wt)</td>
<td>5.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Labour cost ($/tonne)</td>
<td>198.00</td>
<td>165.00</td>
</tr>
<tr>
<td>Average monthly production (tonnes)</td>
<td>24.00</td>
<td>24.00</td>
</tr>
<tr>
<td>Installed capacity (tonnes)</td>
<td>28.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Capacity used</td>
<td>86%</td>
<td>86%</td>
</tr>
<tr>
<td>Sales revenue ($/month)</td>
<td>15,360.00</td>
<td>15,360.00</td>
</tr>
</tbody>
</table>

**Cost sheet (one month production)**

<table>
<thead>
<tr>
<th>Data</th>
<th>Lupin</th>
<th>Mung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw seed cost</td>
<td>1,440.00</td>
<td>5,400.00</td>
</tr>
<tr>
<td>Direct labour</td>
<td>4,752.00</td>
<td>3,960.00</td>
</tr>
<tr>
<td>Water</td>
<td>2,000.00</td>
<td>2,000.00</td>
</tr>
<tr>
<td>Chemicals</td>
<td>260.00</td>
<td>260.00</td>
</tr>
<tr>
<td>Repairs &amp; maintenance</td>
<td>300.00</td>
<td>300.00</td>
</tr>
<tr>
<td>Electric power</td>
<td>300.00</td>
<td>300.00</td>
</tr>
<tr>
<td><strong>Sub total direct costs</strong></td>
<td>9,052.00</td>
<td>12,220.00</td>
</tr>
<tr>
<td>Fixed costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent</td>
<td>1,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Overhead cost</td>
<td>2,000.00</td>
<td>2,000.00</td>
</tr>
<tr>
<td><strong>Sub total fixed costs</strong></td>
<td>3,000.00</td>
<td>3,000.00</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td>12,052.00</td>
<td>15,220.00</td>
</tr>
<tr>
<td>Profit ($/month)</td>
<td>3,308.00</td>
<td>140.00</td>
</tr>
<tr>
<td>Unit cost ($/kg)</td>
<td>0.50</td>
<td>0.63</td>
</tr>
<tr>
<td>Break even point (production- tonnes)</td>
<td>11.41</td>
<td>22.93</td>
</tr>
</tbody>
</table>
Elements of costing

Principal itemized costs

Production volume

The activity level of any organization can be measured to either that of production or sales output (Berry and Jarvis 1991, p. 225).

JAS has eight growing chambers (units) with a capacity of over 35 tonnes of sprouts per month. Actual production varies between 18 and 24 tonnes (after allowing for 20 per cent of wastage) every month depending upon market demand. Lupin sprouts may need to be grown in smaller batches thereby reducing the effective capacity of each unit. It would not be expensive to add an extra growing chamber to these premises. A modified growing room could readily be constructed at a cost and similar growing capacity as that for mung. It is assumed that the facilities could be used equally for lupin and mung.

Raw material costs

The current landed cost of mung seed in Perth is $1350/tonne. Mung beans give about six times the yield of sprouts after allowing for all wastage. The price of mung has increased dramatically in the last year (1992/93) from $800/tonne to $1350/tonne (P. Smith, personal communication, 1993).

The current price (1993) of lupin seed as provided by the Grain Pool of Western Australia, is about $200 per tonne. Graded seed, which has been retained following passage over a 5.5 mm screen to remove immature, cracked seeds and other undesirable matter, purchased for this project, cost $280/tonne. It is assumed that lupin seed of sprouting quality will be available at $300/tonne. The experimental results show that lupin yields about five times its seed weight after allowing for all wastage.
Labour costs

JAS incurs a cost of $1.00 on every kilogram of seed sprouted. This calculates to 16.67 ¢/kg of sprout (T. Smith, personal communication, 1993). For lupin, the equivalent labour cost would be 20 ¢/kg. It is assumed that lupin will need extra labour for cleaning and washing. This is because the existing washing system is not suitable for washing lupin sprouts and the additional labour required is for the manual removal of remaining seed coat. A provision of 25 per cent for the extra work, puts the labour cost at 25 ¢/kg of sprouts.

Other costs

Variable and fixed costs were also considered. Variable costs are the same per unit of activity. Total variable cost increases or decreases in direct proportion to the level of activity. Fixed costs are those which do not change in response to changes in the level of activity (Berry and Jarvis 1991, p. 225). These costs are assumed to be similar for the production of both lupin and mung.

Selling price

The wholesale price for mung bean sprouts is now (1994) 85 ¢/kg. JAS pays $1.05 on a bag of 5 kg for a delivery charge to the delivery contractor. For costing purposes, the net price, after delivery charges, is taken as 64¢/kg. It is assumed that lupin sprouts will sell at the same price.

From this data, calculations were done on profitability, and a break-even and sensitivity analysis (raw material cost, production volume and profits) for mung compared with lupin.

Profitability

Profit represents the difference between the stock at the start and at the end of a period, usually one year. Stock is a static measure, whereas profit is an activity over time (Berry and Jarvis 1991, p. 24).
Profitability is defined as a range of activities and relates to the production levels an enterprise (in this instant JAS) has experienced in the past (Berry and Jarvis 1991, p. 178).

From the costing sheet (Table 14) it appears that mung yields a very small profit at 24 tonnes of monthly production. JAS confirmed that they were operating more or less, on a break-even point because the cost of raw material had increased significantly and the market did not support a higher selling price for mung sprouts. Lupins could show profits at a lower production of 12 tonnes per month and generate a much higher profit at 24 tonnes, the current production of mung sprouts in JAS.

Break-even analysis and profit comparison of mung and lupin sprouts are presented in Figure 23 and Figure 24 respectively. A break-even chart is a method for illustrating the relationship between cost, volume and profits (Berry and Jarvis 1991, p. 237). In the construction of this chart, the variable costs are plotted above the fixed costs, resulting in a total cost function. Fixed costs remain the same throughout the process whereas with every unit produced there is an addition to the variable cost. The main advantage of this kind of analysis to management is that, from the chart, the break-even point and the area of loss and profit can be clearly and quickly identified. This enables management to establish the effect of varying levels of output that they may wish to consider (Berry and Jarvis 1991, p. 237-238). For example, for lupin, the profit output level is 11.4 tonnes per month whereas, in case of mung, JAS needs to produce 23 tonnes per month of sprouts to get to the break-even point.
Figure 23.  Break-even chart (lupin)

Figure 24.  Break-even chart (mung)

-140-
Figure 25. Sensitivity Analysis (lupin)

Figure 26. Sensitivity Analysis (mung)
Unit cost

At average monthly production rates, the unit cost of lupin sprout comes to be 50 ¢/kg compared with 63 ¢/kg for mung. This shows that the growing of lupin sprouts has a clear cost advantage over mung and leaves the manufacturer with a better margin for market promotion (Table 14).

Labour cost

Labour cost paid to the contractor is on the basis of the amount of raw seed used at the start of production and not on the finished product. By this method the contractor does not have any incentive to strive for a better rate of yield. Rather, he is at a disadvantage of providing extra labour for washing and cleaning the sprouts if there is a greater than anticipated yield. I believe that the method of paying labour needs revision.

Sensitivity analysis

Sensitivity analysis is a means of evaluating the effects of uncertainty. It determines how profitability varies as the parameters which effect economic evaluation are varied (Verbaan, 1988, p. 12.3). It is used to make investment decisions from various alternatives, but in my research it is used to determine the critical cost variables that, if changed, could considerably effect profitability. For example, the cost of mung seed has dramatically increased in recent times. This is not likely to be the case for lupin. However, the yield achieved and labour cost associated with cleaning of lupin could vary. The yield of lupin sprout is determined in the same environment as that of mung and labour cost is an estimated cost. The percentage change in profitability caused by the percentage change in value, which is the best estimate in the current situation at JAS, of variables is plotted in Figure 25 and Figure 26.
The order of sensitivity to profit is expressed in the equation:

For mung: Raw seed > Yield > Labour

For lupin: Labour > Raw seed > Yield

As shown in the above equation, and Figure 25 and Figure 26 the profitability of mung is highly sensitive to raw material seed cost as compared with lupin, which means that lupin is profitable to grow under adverse cost situations, whereas mung is profitable to grow under favourable cost situations.

Profitability of lupin is more sensitive to labour cost compared with the raw seed cost or yield. Mung profitability is more sensitive to raw seed cost than labour costs. The manufacturer can then optimize his profits by varying the production of mung and lupin in different cost situations or he may manufacture both in combination.

Lupin provides security of profit compared with mung. However during favourable cost conditions such as lower raw seed cost, mung has the potential of generating higher profits because of its production advantage.

Conclusions

On the basis of production cost calculations, it is advantageous to produce more lupin sprouts then mung at the prevailing price of raw mung seed in Perth. JAS has the experience to know that production is governed by market demand and, on various occasions, they have to operate at much lower production levels.

Profitability calculations show that, lupin could break-even at a lower volume of monthly production than mung (11.41 to 23 tonnes). This indicates that it is more profitable to grow lupin sprouts when the demand (or sale) for sprouts is less. In the case where demand is lower than 23 tonnes per month, the production of mung sprouts certainly show relatively high losses.
Lupin provides security of profit compared with mung. However, during favourable cost conditions such as lower mung raw seed cost, mung has the potential of generating higher profits because of its value-added weight advantage.

The conclusions to be derived are that the growing of lupin sprouts has a clear cost advantage over mung and leaves the manufacturer with a better margin for market promotion. The calculations are based on the assumption that a manufacturer could substitute lupin for mung in the market place and make the best use of existing facilities to achieve maximum profits. This may or may not be true, because lupin sprouts and mung may not be considered similar sprouts by the consumer.
CHAPTER 8

Consumer research

Introduction

From the information now provided in this thesis as a result of my research it does not necessarily mean that mung and lupin sprouts are regarded as alternatives by the end consumer of bean sprouts. From the consumer's point of view, mung and lupin sprouts may well be regarded as equivalent in terms of taste and appearance. Consumers may believe that lupin sprouts can be used as a food in much the same way as they traditionally use mung and, perhaps, other bean sprouts.

Many factors may influence the final consumer with respect to their selection and use of foods such as bean sprouts. Sensory or eating characteristics such as taste, texture and appearance, as well as psychologically based factors which are more related to learned patterns of usage of the food are such examples. There seem to be marked differences between Australians and members of other cultures as regard the role of bean sprouts in their traditional diets.

Bean sprouts have a long history as a staple and significant ingredient in the food habits of many Asian cultures. Their use in Australia by Caucasian consumers is relatively recent and of much less significance in daily dietary patterns. These cultural influences may well have a considerable bearing on the food perceptions and preferences of individuals from different cultures. Asian consumers may prefer mung sprouts over lupin sprouts because they have characteristics which are culturally familiar to them. However, Caucasians may either have no preference for the different types of sprouts or may even prefer lupin sprouts over the mung sprouts for other reasons. These matters were examined before any firm conclusions were drawn about the commercial viability of lupin sprouts.

-145-
There are two major markets for lupin sprouts. The largest and potentially most profitable includes those off-shore cultures in Asia and South East Asia in which sprouts are used as a regular component of daily food patterns. This includes countries such as Japan, China, Taiwan, Singapore, Burma, Thailand, Laos, Kampuchea (Cambodia), Vietnam, Malaysia, Indonesia and the Philippines. It is this extremely large and valuable market which would be of particular interest to Australian growers and producers of lupin based products.

The second is the Australian domestic market which, while much smaller than the export market, could provide considerable financial returns to lupin growers as well as down-stream processors.

To exploit either or both of these market opportunities, information needed to be gathered about the attitudes, shopping and eating habits of members of these two cultural groups in relation to fresh sprouts. An experiment was planned which involved the collection of survey data from members of these two cultural groups.

Beans sprouts in Asian and Australian diets

Review of cultural differences

Culture is defined as the knowledge, belief, customs and habits shared by a group of people. These patterned behaviours are learned, not inherited. Culture is passed from generation to generation through the process known as enculturation (Kittler and Sucher 1989, p. 5). Children learn their culture from their parents and also from the wider society around them. For about 40 per cent of Australian school children, the culture of their parents is different from that of the wider society and sometime Australian children face cultural conflicts (O'Brien and Thodey 1988, p. 47-48).
Culture significantly determines an individual’s food habits. The term ‘food habit’ refers to the ways in which humans use food. It includes how food is obtained and stored, how it is prepared and served and to whom and how it is consumed (Kittler and Sucher 1989, p. 4).

**Chinese or South East Asian food patterns**

The food style of a culture is determined by the natural food resources available for its use. It is not surprising that Chinese food is, above all, characterized by an assemblage of plants and animals that have thrived in China for a long time (Chang 1977, p. 7).

The average Chinese customarily eats three meals a day, plus numerous snacks. A survey on adaptation of food habits by Chinese in the United States shows that the changes in eating habits correlate with increasing length of stay in the United States. Dinner remains the most traditionally Chinese meal, whereas breakfast, lunch and snacks tend to become more Americanized (Kittler and Sucher 1989, p. 264 and 267).

The survey reported that elderly Chinese usually eat an almost completely traditional diet. Those with higher educational levels however, tend to consume more American foods. Most of the Chinese attempt to balance hot and cold foods (Kittler and Sucher 1989, p. 268).

Chinese consumers usually strive to obtain the freshest ingredients for their meals. Most Chinese food is cooked with very little raw food, except fruit, being eaten. Cooked foods may be eaten hot or cold. Common cooking methods are stir-frying, steaming, deep fat frying, simmering and roasting. In stir-frying, foods are cut into uniform, bite-sized pieces and quickly cooked in a wok in which oil has been heated (Kittler and Sucher 1989, p. 263).

While Japanese foodstuffs, cooking and eating utensils are similar to those used by the Chinese, because of the strong cultural influence China has had on Japan from...
the 6th century, Japanese food preparation and presentation methods are unique (Kittler and Sucher 1989, p. 275). Traditionally, Japanese eat three meals a day plus a snack called Oyatsu. Snacks usually consist of several sweets, rice crackers or fruit (Kittler and Sucher 1989, p. 268).

In Japanese diets, fresh foods and vegetable are most desirable and are eaten only when in season. Pickled vegetables are available all year round and are extensively eaten. Fresh fruit is the traditional dessert (Kittler and Sucher 1989, p. 281).

In America, second generation Japanese-Americans eat a typical American diet, but eat more rice and more soy sauce than do non-Asians. Traditional foods are prepared for special occasions. Third and fourth generation Japanese-Americans appear to be totally accustomed to American ways of eating food. Even in Japan, a Westernised diet is increasingly popular. Bread and butter are becoming dietary staples and the consumption of milk and eggs is increasing (Kittler and Sucher 1989, p. 283-284).

South East Asia is a tropical region south of China and east of India whose lands straddle the equator. It includes the countries of Burma, Thailand, Laos, Kampuchea (Cambodia), Vietnam, Malaysia, Indonesia, Singapore and the Philippines. These countries are similar in climate, flora and fauna. Much of the history of South East Asia includes long periods of foreign domination, firstly by other Asiatic nations and later by the Europeans. The various cuisines of South East Asia share many similarities in ingredients, but food preparation methods and meal patterns often reflect the foreign cultures that have influenced the individual countries (Kittler and Sucher 1989, p. 285-288 and 292).

The Vietnamese cuisine, for example, is closely related to southern Chinese cuisine. The Vietnamese serve many uncooked vegetables, often in the form of salads and pickles (Kittler and Sucher 1989, p. 298).
Australian (or Caucasian) food patterns

Australia was originally colonized by the Aborigines and later by the British. The basic food eating patterns today are influenced by British styles of eating. Another important influence on food patterns is that caused by non British migration to Australia (O'Brien and Thodey 1988, p. 54).

The Australian consumer of today is influenced by the food habits and patterns of non British migrants and many have adopted sprouts as a 'health ingredient'. Bean sprouts are traditionally used by Asian communities for stir-fries. In Australia, sprouts were rediscovered in the early 1970s by health proponents. Since then, Caucasian users have created different forms and customs in the use of sprouts as a food ingredient. Sprouts are now frequently used in Australia in salads and as a sandwich filling, rather than as a stir-fry ingredient. There is a greater variety of sprouts on the market in Australia than ever before. The varieties more commonly seen in Perth are: alfalfa, radish, mustard, mixed sprouts, lentils, peas and mung bean sprouts.

Consumer survey - 1993

Methods

Respondents

The respondents to the survey were not a randomized sample, but were female shoppers who agreed to participate in the survey. All respondents agreed that they regularly bought fresh bean sprouts. Respondents were selected by ethnic origin and were of an age range from 20 to 50+ years.
Location

Equal numbers of Asian and Caucasian respondents were intercepted while shopping in the following Perth metropolitan shopping centres: Morley, Riverton, Midland, Winthrop, Karrinyup, Broadway and Brisbane Street in North Perth.

Interviewers

The interviewers were either senior year female university students or mature age adults. All had experience and/or training in face-to-face interviewing techniques.

Filter question

A filter question ‘Do you ever buy sprouts' was asked of each respondent by the interviewer. If answer to this was ‘No', the interview was politely discontinued. If the answer was ‘Yes' then further questions were asked.

Test questions

An interviewer completed a structured questionnaire which was designed to provide data on the following issues. The questionnaire was pilot tested on members of the target groups and assessed by Dr F. Flanagan of Edith Cowan University.

Scope of questions:

- Sensory evaluation of lupin and mung sprouts.
- Recall and recognition of varieties of fresh sprouts.
- Buying habits and selection criteria.
- Reasons for buying fresh sprouts.
- Frequency of usage of fresh sprouts.
Questionnaire
Sprout survey 1993 
Interviewer/loc 

(Circle and write in all answers as appropriate)
Do you ever buy fresh sprouts (filter) 
Yes/No
Age 20/30/40/55+
Country 
In Australia 

Question 1
Would you please compare these sprouts in terms of
Which sample has the better appearance? + V Equal
Which sample has the more pleasant flavour? + V Equal
Which sample has the better texture? + V Equal
Which sample do you prefer overall? + V Equal

Question 2
Which sample would you use as a snack? + V Both Neither
Which would you as a salad vegetable? + V Both Neither
Which would you put into sandwiches? + V Both Neither
Which would you cook in a stir-fry? + V Both Neither

Question 3
Could you give me the names of any sprouts you have ever bought?
1. 
2. 
3. 
4. 

Question 4
Where have you bought them?
Supermarket/Fruit/Health shop

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**Question 5**

Have you ever bought any of these types of sprouts?

<table>
<thead>
<tr>
<th>Type</th>
<th>Loose or in punnets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mung</td>
<td>Yes/No/Not sure</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Yes/No/Not sure</td>
</tr>
<tr>
<td>Lupin</td>
<td>Yes/No/Not sure</td>
</tr>
<tr>
<td>Others</td>
<td>Yes/No/Not sure</td>
</tr>
</tbody>
</table>

**Question 6**

Would you be likely to buy any of these sprouts if you saw them in a shop?

<table>
<thead>
<tr>
<th>Photo</th>
<th>Yes/No/Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

**Question 7**

Please put the main reasons for buying sprouts in order of importance to you (read) (most important first)

<table>
<thead>
<tr>
<th>Reason</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td></td>
</tr>
<tr>
<td>Taste</td>
<td></td>
</tr>
<tr>
<td>Change/variety</td>
<td></td>
</tr>
</tbody>
</table>

**Question 8**

How does family usually eat them? (tick)

<table>
<thead>
<tr>
<th>Snack</th>
<th>Salad</th>
<th>Stir-fry</th>
<th>Sandwich</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 9**

Which of your family members like to eat sprouts?

<table>
<thead>
<tr>
<th>Adults</th>
<th>Children</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/Female</td>
<td>Male/Female</td>
<td>Male/Female</td>
</tr>
</tbody>
</table>

**Question 10**

Would you prefer to buy them with the seed shell (coat)

<table>
<thead>
<tr>
<th>On/Off/Either</th>
<th>On/Off/Either</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Would you prefer to buy them with the root stem

<table>
<thead>
<tr>
<th>On/Off/Either</th>
<th>On/Off/Either</th>
</tr>
</thead>
</table>
**Question 11**

Fresh sprouts are usually sold at about 5 to 7 days old. If you bought them while they were still growing would you prefer to buy at ____________ 1 2 3 4 5 6 7 days old.

**Question 12**

If you bought the growing sprouts where would you be most likely to keep them in the home?

In fridge/on shelf or bench/outside house/other ____________

Reasons why you would store them there ____________________________________________________________________________________________

**Question 6**

Photograph showing three types of unnamed sprouts all in different containers.

(A) Pea sprouts in an opaque container.
(B) Alfalfa sprouts in a clear container.
(C) Mung sprouts in a plastic bag.

Neither the type of sprouts or packaging was discussed with the experiments.
Data analysis

Quantitative data were statistically analysed using the Minitab statistical package (see Appendix 7). Qualitative data were pre-coded where possible before conducting the interviews to allow responses to be directly comparable.

The results were recorded in a standard written format. Tables and graphs were used where necessary.

Results

Demographic characteristics

There were 228 female shoppers, who stated that they were retail buyers of fresh bean sprouts and who agreed to participate in the survey.

Respondents were asked to state their age (in decades). The results as shown in Table 15 were as follows:

<table>
<thead>
<tr>
<th></th>
<th>20s</th>
<th>30s</th>
<th>40s</th>
<th>50+</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>29</td>
<td>18</td>
<td>29</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Asian</td>
<td>34</td>
<td>27</td>
<td>24</td>
<td>15</td>
<td>26</td>
</tr>
</tbody>
</table>

These data are presented graphically as shown in Figure 27.
The South East Asian and Caucasian respondents were similar with regard to age although the Asian respondents were slightly younger. This should make little difference to the responses to the questionnaire.

**Appearance evaluation**

The literature abounds with evidence of the importance of physical appearance as a criterion for the selection of fresh fruit and vegetables (F. Flanagan, personal communication 1993). In marketing parlance, it is often stated that consumers buy a product for the first time with their eyes. The appearance of a product is probably the major factor which determines whether a consumer will try a new product.

Respondents were shown mung and lupin sprouts and asked to state which of the sprouts they preferred on appearance alone. They had no prior knowledge of the types of sprouts being compared. It was predicted that Asian consumers would more likely prefer mung sprouts, because this is the market leader and should be familiar to most Asian respondents. Results from a pilot study of Caucasians by Yates (1992) suggest that Caucasians may have a slight preference for lupin sprouts.
The results for appearance are presented in Figure 28.

![Figure 28. Preference for appearance.](image)

There were no significant differences between the preferences of either group for mung or lupin sprouts. The Caucasian respondents slightly preferred the appearance of the lupin sprouts while the Asian respondents slightly preferred the mung sprouts but neither group showed a significant preference for either.

A larger percentage of Asian consumers, compared with Caucasians, rated them as equally acceptable. This suggests that, for these consumers, any differences in appearance are not important to their buying decisions.

The results of the survey showed that the appearance of lupin sprouts is as acceptable to both groups as is the appearance of the standard market product. This is regarded as a promising result, particularly given the responses from Asian consumers. This is a strong indication that there may be potential for lupin sprouts in the large and profitable off-shore markets and also on the domestic market.

**Eating characteristics**

People do not primarily eat because they recognize that the living body has a physiological need for a group of chemicals to preserve its structural and functional
integrity over time. Most people eat a food because they like it. Food intake is not completely driven by hedonicstic motives. Opinion and beliefs also play an important part in food usage. Taste only contributes partially to the total perception of an item or food. In many cases, the smell of food is more important than the taste. The feel of food related to texture, as well as temperature, also contributes to the complex perception in the selection of foods. While consumers may buy for the first time with their eyes, they buy from then on with their mouth (Kroeze 1990, p. 41).

**Flavour**

The chemical senses, taste, smell and trigeminal sensitivity play an important role in preparing the body for food and signalling information about its nature and palatability. The sense of taste alerts the brain to the presence of sweet, sour, bitter and salty substances in the oral cavity. The sense of smell process is associated with the volatiles which produce the subtleties and complexities of food flavours. Odours can reach the olfactory receptors both through the nose and through the mouth. The trigeminal sense provides the brain with the information about other sensations in the oral and nasal cavity: warmth, cold, irritation, pungency (Murphy and Gilmore 1990, p. 19). Flavour is probably the most important reason for repeat buying of a food product (F. Flanagan, personal communication, November 1993).

The respondents were asked to compare the flavour of the sprouts. It is predicted that more Asian consumers would prefer mung and that Caucasian consumers would find lupin to be as acceptable as mung.

The results for flavour are seen in Figure 29.
Mung was clearly preferred by both Asian and Caucasian consumers by relatively large margins, but there was acceptance of the flavour of lupin by about 30 per cent of Asians and about 40 per cent of Caucasians. It appears that, if anything, lupin had a taste which was acceptable to many Caucasian consumers. While the flavour of lupin is not as preferred overall, there are still large numbers of respondents from both ethnic groups who prefer it over mung, the standard market leader. This shows that, by flavour alone, lupin sprouts have an acceptable flavour for many potential consumers.

**Texture**

Texture is defined as a sensory attribute and is only measurable by directly sensory means; touch, sight and hearing (Brennan 1984, p. 59). Bean sprouts are used as a vegetable by Asians and Caucasians. Most Asians prefer the chewy texture of mung bean sprouts, while many Caucasians seem to prefer crisper sprouts in their meals. The lupin sprout is more crisp than mung and it could be expected that more Caucasians would prefer lupin over mung. The results for texture are shown in Figure 30.
Sensory preference

Sensory preference is a combination of each of the previous responses. On this basis, it is likely that most Asian respondents would choose mung sprouts because of their preference for its flavour and texture. The preferences for Caucasians are not as predictable because Caucasian respondents mostly preferred mung for its flavour and lupin for its eating texture. It is not expected that the slight preference for the appearance of lupin sprouts would make any difference with regard to their acceptability.

The results of the combined preference are presented in Figure 31.

Figure 31. Combined preferences of lupin compared with mung.

Mung was preferred by more respondents from both groups. As anticipated, the preference for mung sprouts was much greater among Asian respondents with only about 30 per cent preferring lupin sprouts.

The results showed that the Caucasian respondents also preferred mung sprouts, but the preference rate for lupin was higher at 40 per cent.
Summary

Results of appearance, flavour, texture and overall combined preference for lupin and mung sprouts are presented in Figure 32.

![Figure 32](image)

Figure 32. Comparison of appearance, flavour, texture and overall combined preference for lupin and mung sprouts.

Most consumers in this survey preferred mung sprouts to lupin sprouts. Preference seemed to be mostly based on flavour rather than on appearance or texture. This evidence agrees with that of other studies which showed that flavour is the most important attribute in determining the acceptability of fresh foods.

In addition, there is a cultural difference in that more Asian respondents are likely to select mung sprouts whereas Caucasian respondents were more evenly divided although a majority preferred mung to lupin sprouts.
Nevertheless, the results showed some level of acceptance for the eating characteristics of lupin sprouts and that, in particular, there may be a place for them on the domestic retail market-place.

**Perceived uses of mung and lupin sprouts**

While mung sprouts have a long history of use as a food or food ingredient in many Asian countries, lupin sprouts have never been sold commercially in Australia. If lupin sprouts are to be commercially acceptable on either the domestic or off-shore markets, then they would have to be accepted by consumers as suitable for incorporation in their daily diets.

*Use as stir-fry*

Stir-fry is generally regarded as the most frequent use of mung sprouts. South East Asians in particular, like to eat cooked sprouts in this form. In stir-frying, foods are cut into uniform, bite-sized pieces and quickly cooked in a wok in which oil has been heated (Kittler and Sucher 1989, p. 263). Since such a dish is made of a mixture of ingredients, its distinctive appearance, taste and flavour does not depend on the exact number of ingredients nor in most cases, on any single item. This suggests that lupin sprouts may be acceptable as a stir-fry ingredient by South East Asian consumers as well as Caucasians. Yates (1992) compared mung sprouts with lupin sprouts in stir-fries on the basis of sensory characteristics. She found that the lupin sprouts were not as acceptable as mung sprouts when used as an ingredient in stir-fry vegetables. They were found to be less chewy and had a less salty flavour. As a consequence, it is difficult to predict whether lupin will be perceived as an appropriate ingredient for stir-fry by the respondents involved in this research.

Results of ‘Use as a stir-fry’ are presented in Figure 33.
While more Asian respondents than Caucasians preferred mung sprouts rather than lupin sprouts as a stir-fry ingredient there was a small majority of Caucasian respondents who stated that they would use lupin as a stir-fry ingredient. Nevertheless, there were sizeable minorities of both Asian and Caucasian respondents who said that they would use both legumes. This shows that lupin could be accepted as a stir-fry ingredient by both Asian and Caucasian consumers.

**Use as a snack**

Both Chinese and Caucasian people have 'between meal' snacks as a significant part of their daily eating pattern. What they eat as a snack is influenced by culture, food habits and diversity of items available. Fresh fruit and a few vegetables are viewed as snack foods which, are readily available for consumption in Australia. However, many consumers still tend to purchase foods which, are high in calories and low in nutritional value. The habit of snacking is growing rapidly as the availability of snack foods increases. Snacks have now become a significant part of the Australian diet (McClure 1990, p. 24). A study reported in 'Food Australia' in February 1990,
examined the nutrient composition of some Australian snack foods. Seven potato-based snack foods, one corn based and salted peanuts were analysed for nutritive value. It was found that the major components of these foods were starch and fat, which, together accounted for about 80 g of the 100 g examined. Other common snack foods include biscuits and cakes which have high sugar content.

Today, consumers demand fast, convenient foods which are not necessarily nutritious. Although this is not about to change overnight, consumer attitudes towards a healthier diet may lead to the opportunity for a change in market direction (The Australian Horticultural Corporation 1989, p. 6).

Nutritionally, fresh sprouts would be a much healthier snack than many other foods on the market. This may be a market segment which could be targeted as a use of lupin sprouts. Consumers are certainly more nutritionally aware than previously, though about 30 per cent of today’s food budget is spent on foods which are eaten away from home. As such, the fast food industry continues to prosper (Stone 1988, p. 144). There is little evidence which can be used to indicate the extent to which Asian consumers eat fresh raw sprouts as a snack food so that it is difficult to predict this use of sprouts. Figure 34 shows the percentage responses of Caucasians and South East Asians on their use of sprouts as a snack.
Figure 34. Sprouts: use as a snack.

It seems that Caucasian consumers are more likely to eat fresh sprouts as a snack food while the vast majority of Asians would not eat sprouts in this way.

If there is a potential market for fresh sprouts as a snack food, then it would be in the domestic rather than the off-shore market. For those who would eat sprouts as a snack, the choice of Caucasian respondents was equally divided between mung and lupin, while those Asian respondents, who were more likely to choose sprouts as a snack, would choose mung sprouts.

Cultural differences in sprout preferences are quite marked, with Asian respondents more likely to prefer the more familiar mung sprouts. Unfortunately, the results suggest that very few Asians regarded raw sprouts as a snack food, so that this potentially profitable off-shore market appears to be very limited.

Use as a sandwich filling

Sandwiches are usually associated with Western culture. However, the influence of the interaction between Asians and Caucasian groups in Australia has made sandwiches popular amongst all cultures. This agrees with the work of Kittler and
Sucher (1989) who found in their survey that changes in eating habits correlate with increasing length of stay in the United States. Sandwiches are most popular because they are quick to prepare and easy to handle for luncheon or snack.

While sprouts are not widely used as a sandwich filling, they are seen as an acceptable type of filling, particularly given the rapid increase in interest in the nutritional aspects of this type of light snack or small meal.

Various sprouts such as alfalfa, radish and onion sprouts can be used as a sandwich filling, but the sprout most widely used for the purpose is likely to be the market leader, mung sprouts. The extent that lupin sprouts will be accepted as a sandwich filling is not known, but it is likely that more Caucasians than Asians would use lupin sprouts as a filling.

Figure 35 shows the results on the use of lupin and mung as sandwich fillings.

![Figure 35. Use as a sandwich filling.](image)

It is clear from the results that very few Asian respondents would use sprouts of any kind as a sandwich filling. Of those who said that they do, most would be likely to use mung and not lupin. Interestingly, the majority of Caucasian respondents would
use raw sprouts as a sandwich filling and most of those would choose mung. This means that there may be a small, but profitable market for sprouts as a sandwich filling, though it would be a domestic market targeted mainly at Caucasian consumers.

*Use as a fresh salad vegetable*

Salad is usually a mixture of raw vegetables and fruits, but cooked and pickled foods can also be included. Salads can be served as a starter to a meal, as an accompaniment to a main course or as a complete main course. Salads are nutritionally important because they add bulk to the diet and provide fibre, vitamins and minerals, particularly if raw vegetables and fruits are used (Tull 1985, p. 227).

As a rule, South East Asians, except Vietnamese, do not use raw ingredients, including vegetables, other than fruit in their diet. Caucasians use more salads than Asians in their diets. Fruit and vegetable promotional campaigns in Australia encourage the use of sprouts in salads. Several cookery books include recipes with mung bean sprouts, alfalfa sprouts, radish and mustard sprouts as an ingredient in salad. Since mung bean is familiar as a salad ingredient, it could be expected that lupin could be used as a salad especially because of its better appearance over mung sprouts. Likewise, more Caucasians would use either of the sprouts than Asians.

Results of 'Use as a salad' are presented in Figure 36.
The results confirm other findings which found that a large number of Asians rarely eat sprouts as a raw food. Of those who would use them as a salad ingredient, most would prefer mung, although a large minority said that they would use either mung or lupin in this way.

Most Caucasians said that they would use sprouts in salad, but most would prefer mung as the salad ingredient. There seems to be only a limited market for this use of lupin sprouts.

**Summary of sprout use**

The use of sprouts are tabulated in Figure 37.
Figure 37. Sprout use.

The combined results show that the most frequent use of fresh sprouts was as a cooked vegetable in stir-fries for both groups of respondents, while fresh sprouts were more likely to be used as a salad ingredient rather than as a snack food or a sandwich filling. For stir-fry, mung was preferred by Asian consumers, but a larger proportion of Caucasians would choose lupin for that use.

For the total sample of respondents, mung was preferred over lupin for all purposes.

As regard cultural differences, the results indicated that Asian respondents are more likely to use sprouts as a cooked food, while more Caucasians were likely to eat them raw in salads, as a snack or as a filling.

Most respondents perceive mung and lupin sprouts as having different uses and that they are not direct substitutes for each other in food use. Given that lupin sprouts were totally unfamiliar to the respondents in this survey, the results suggest that, with promotion, there may be place in the market-place for lupin as a new type of fresh sprout.
Unprompted recall and recognition of sprouts

A cursory examination of the Perth retail market-place shows that there is an almost total absence of any media or point-of-sale material of any kind relating to bean or another sprouts. There are no shelf talkers or labelling information designed to inform consumers of the presence of fresh sprouts. Mung sprouts are sold in large, open plastic bags, which contain no details of the product except for the statement "bean sprouts" and the price per kilogram which is written on a card by the retailer.

This lack of promotional effort means that sprouts will not be prominent in the mind of consumers. As such, they are unlikely to be a planned or deliberate purchase on the part of the average consumer. Under such circumstances, sprouts certainly are not likely to be perceived as a high priority or high priced commodity in strong demand by consumers.

Unprompted recall

A series of questions was asked of consumers to determine the extent to which they were aware of sprouts as a food item in retail stores.

Respondents were simply asked, without prompting, to name any type of sprouts they have ever bought. It was anticipated that mung would be mentioned by Asian respondents in particular, but because sprouts are not named at the point-of-sale, few Caucasians were expected to recall sprout names. Respondents were asked to name four types they could recall.

The answers of first mention, second mention and third mention are presented in Figure 38, Figure 39 and Figure 40 respectively.
Figure 38. Name of sprout ever bought, first mention.

Figure 39. Name of sprout ever bought, second mention.
The unprompted recall rate for the market leader mung is very low for both Asian and Caucasian respondents. This appears to accurately reflect the almost total lack of marketing effort in Perth and could be interpreted as an unfulfilled marketing opportunity for sprout processors.

By far the most frequently named sprout was alfalfa which is sold in small covered plastic containers which mention both the name of the sprout and the grower or packer. The recall rate is particularly high for Caucasians, which suggests that a very simple and inexpensive promotional strategy can make the majority of consumers more aware of the availability of this type of product.

The generic name 'bean sprouts' was mentioned by some respondents, as was the vegetable 'Brussel sprouts'. Other sprouts which were recalled by a few respondents included clover, radish, onion, bamboo, broad beans, sunflower, mango, salad sprout, soy sprout, cress and fenugreek. The results showed that very few Asian or Caucasian respondents were able to easily retrieve the name of mung sprouts. This probably means that promotion of these types of sprouts are far less than optimum and that there is considerable potential for expanding this market.
Recognition

While respondents may have difficulty in recalling, without prompting, the name of particular varieties of bean sprouts, this does not necessarily mean that they are unable to recognize specific variety names when reminded of them. In this recall questionnaire the name of 'lupin sprouts' was included as a validity check. As lupin sprouts have never been sold on the retail market few, if any, respondents would have heard of them. A high positive response rate would then indicate the extent of misreporting within the questionnaire.

It was expected that the positive response rates to alfalfa and mung would be higher after prompting than without prompting.

The results of prompted recall are presented in Figures 41 to Figure 46.

Figure 41. Have you ever bought alfalfa?
Figure 42. Alfalfa loose or in a punnet?

Figure 43. Have you ever bought mung?
Figure 44. Mung: loose or in punnet?

Figure 45. Have you ever bought lupin?
The prompted recall of alfalfa was more than the unprompted response. These sprouts are sold mostly in labelled punnets and it seems that most consumers can recall this information from the package even though the information supplied is very little. Large majorities of both Caucasians and Asian respondents stated that they had bought alfalfa sprouts in punnets which confirms that the most of these sprouts are sold pre-packaged in punnets.

The prompted recall of mung was greater than the previous unprompted recall, but was still lower than the alfalfa recall. As mung sprouts are usually bought loose in unlabelled plastic bags, it is not surprising that there were large numbers of respondents who did not remember buying mung.

The validity check question on lupin sprouts gave an honest assessment by the respondents. Large majorities of both groups said that they had not bought any lupin sprouts. This means that most of the respondents surveyed correctly answered the question.
Marketing and promotion of sprouts

Reasons for buying

Consumers were asked why they bought sprouts. This was done because the answer given could have an influence upon how sprouts are marketed to various target groups. For instance, if sprouts are bought because they are healthy or nutritious then price may not be a critical factor. This implies that consumers may buy packed sprouts even if prices were a little higher than loose sprouts. Alternatively, if price is of major concern to the consumers, then probably loose selling would be appropriate. If the sprouts are bought just for taste, this may imply that the consumer is flexible enough to buy various varieties, or would prefer a range of sprouts from which to choose. If change or variety is not the main concern, then perhaps the consumer has sprouts as a staple ingredient in their diet.

A summary of preferences ranking order is presented in Figure 47.

![Figure 47](image)

Figure 47. Order of preference (weighted ranking).

Caucasian consumers rated nutritional value as the most important reason for buying sprouts. Hence, if lupin sprouts were promoted with the emphasis on nutrition, then...
perhaps Caucasian consumers would buy them. Taste was more important than change or variety and price was of least concern.

South East Asian consumers were less in agreement in the answers and reasons given as to why they bought sprouts. Taste was more important than nutritional value. This suggests that if lupin is to be promoted as a substitute to mung, then it has to be similar in taste. This may not be possible to achieve. It would not be wise to liken mung and lupin with regards to taste as the two are not substitutes for each other on this criterion. Price was more important to South East Asian than Caucasian respondents. Change or variety was of least concern for Asian respondents when buying sprouts since mung sprouts are a staple in their diets.

As the two cultural groups differ in their reasons for buying sprouts, this suggests that two different market segments exist. This means that different marketing strategies for the promotion of existing sprouts, or the new proposed lupin sprouts, to domestic or off-shore markets is required.

Point of purchase

Consumers were asked as to where they purchased sprouts. The aim was to identify the retail outlets from which they currently purchased their requirements to provide information relevant to the distribution of fresh sprouts. Retail outlets identified were supermarkets, fruit and vegetable shops and health food shops. Almost all the fresh vegetable and fruit shops sell sprouts. Since more people have become interested in natural and/or untreated organically grown food, many health food stores have begun to stock seeds for sprouting, equipment for home sprouting and sprouted seeds. Most stores that specialize in Oriental foods sell sprouts, particularly mung sprouts which are widely used in Eastern dishes. Multiple replies were allowed in this question.

The results are shown in Figure 48.
The supermarket, one-stop-shop, seems to be the most convenient purchase point for the consumers from both cultures. Caucasians seem to depend on fruit and vegetable shops as well. South East Asians rely as equally on fruit and vegetable shops and gourmet shops. The implication here is that, if lupin is to be sold to consumers the above mentioned purchase points need to be considered in domestic market promotions.

Packaging and presentation of sprouts

Packaging involves promoting and protecting the product. Packaging can be important to both sellers and customers. Packaging also makes products easier to identify and promotes the brand at the point of purchase and even its use (McCarthy and Perreault 1987, p. 243).

Mung sprouts are now sold to the retail supplier in large, unbranded open bags from which the final customer selects the amount of sprouts required. Essentially, mung sprouts are sold as a generic product and bought in bulk.
I considered that this generic approach to the selling of mung sprouts may produce consumer resistance on health grounds, and because the sprouts look unattractive unless they are in peak condition. The consequences of this may be low demand and poor prices for sprouts presented for sale in this manner. Other sprouts are sold in enclosed plastic punnets which usually contains information about the sprout variety and the grower of the sprout.

Alfalfa sprouts are sold in an enclosed punnet as a 'green top' growing product. Another approach is to provide the consumer with 'sprouting seeds' in an enclosed punnet. Unlike mung sprouts which are harvested before sale, both the lucerne alfalfa and the sprouting seeds are still growing when they are purchased.

Consumers were asked if they preferred to buy sprouts which were still growing and therefore as fresh as possible when they are consumed. The aim of this question was to test the hypothesis that consumers are resistant to buying sprouts which are sold in open, unbranded bags and would prefer to buy sprouts which are enclosed in protective packaging. Consumers were shown photographs of each of three forms of packaging. They were asked if they would buy sprouts packaged in that form, and to state either why or why not. The results to the questions relating to each type of packaging is as follows.

Mung (loose in bag) (Photo C). There is virtually no evidence of buyer resistance to mung beans packed as a generic product. A large majority of both Caucasian and Asian respondents stated that they would buy sprouts in this form. The main reasons given seemed to be related to familiarity with the product in that this is how bean sprouts are traditionally sold. There was no evidence of any awareness of health issues or of a lack of product information.

Alfalfa (green top) (Photo B). There was a very high positive response to the growing alfalfa in an enclosed punnet. Caucasian respondents in particular, found the appearance of these sprouts to be attractive as the product looked fresh and healthy. While many Asian consumers also stated that they would buy these sprouts...
in this package, the response rate was lower simply because relatively few Asians eat sprouts raw. They prefer to cook them in stir-fries and growing alfalfa is not seen as suitable for that purpose.

Sprouting seeds (Photo A): Most consumers said that they would not buy this type of sprout. Many did not like the appearance of the seeds, which some interpreted as being 'old' or 'stale' seeds, rather than fresh living sprouts. Respondents were shown a photograph of commercially presented sprouts. The results to the question are presented in Figure 49, Figure 50 and Figure 51.

![Figure 49](image)

Figure 49. Would you buy: Photo A (opaque container; just sprouted seeds).
Figure 50. Would you buy: Photo B (alfalfa sprouts).

Figure 51. Would you buy: Photo C (Loose mung bean sprouts).

There is no evidence of buyer awareness of any health concerns about buying mung sprouts in open bags, but a number complained about the lack of product information associated with that selling method (variety name and recipe suggestions) Buyers felt that the longer, stringy mung (and lupin) sprouts were unsuitable for selling in plastic punnets, whereas the shorter, green topped alfalfa was well suited for selling by this method.
There is no evidence that respondents prefer to harvest their sprouts directly from the punnet. They seem more likely to store the sprouts in the refrigerator rather than leave them on a shelf to harvest, or to plant them in the garden. This being so, the current method of selling mung in loose bags appears to be satisfactory to most of the respondents surveyed, despite its apparently obvious disadvantages.

**Reason for buying sprouts**

Consumers were asked if and why they would buy a particular sprout from the photographs shown. Some of the reasons mentioned by the respondents were that sprouts were good for sandwiches, cooking, stir-fry, Chinese dishes and salads. Other opinions were that consumers use sprouts because they are familiar with them, or they have used them at home (or mother used them).

The reasons given for not using sprouts were because sprouts were not familiar to them or never used at home. Few Asians would use alfalfa because these cannot be stir-fried. Most Caucasians bought sprouts because of their appearance. Just sprouted seeds were not bought by most of the respondents because of their shell-like appearance and because they did not know how to use them. Other reasons justifying the purchase were flavour, taste, cheap and fresh, healthy, traditional, family likes them or husband likes them.

In addition to the above, some unique responses were given. It seems packaging is of concern to a few respondents as these respondents mentioned that they would only buy sprouts in covered containers. Opaque containers were considered as not suitable for the growing sprouts. Another interesting suggestion was that the respondents would buy more quantities of mung sprouts if these had a better shelf life. Others would buy if they knew ‘how to use’ them. This suggests that if packaging carried some instructions on usage, or a recipe on how to cook them, then perhaps there would be more consumers buying sprouts. Some consumers were concerned that just sprouting seeds do not keep well. They wanted the sprouts to
have a shelf life at least equivalent to that of other sprouts such as alfalfa. Evidence for this observation was noted during the research (see Appendix 8); the sprouts were very young, and the packaging container did not allow them to be rinsed often enough thus permitting an increase in the microbial loading and hence a decrease in shelf life.

In short, different varieties of sprouts are bought for specific reasons and use. This is important for lupin sprouts, as any promotional campaign has to be aligned with the best feature of the sprouts as perceived by consumers.

Seasonal use of fresh sprout

Different kinds of food stuff are eaten by people in different seasons. Sandwiches, bread rolls and salads are more popular in summer and soup, stir-fry and hot pies would be more popular in winter (O'Brien and Thodey 1988, p. 67). A survey on food patterns of Australians at the beginning of the 20th century suggests that more salads and vegetables were consumed on weekends and summer than at other times (Teow, Wahlqvist and Flint 1988, p. 66). It is expected that most respondents from both cultures would use sprouts for stir-frying irrespective of the season. It is likely that more respondents would use sprouts as a salad and sandwich filling rather than sprouts for snacks in summer.

The variation of the use of sprouts in different seasons is presented in Figure 52.
The most popular use of sprouts is expected to be stir-fry irrespective of the season. In summer, more consumers are likely to use sprouts for salads and sandwich filling. This would mean that, if lupins are to be used by the consumers, it is more likely that this is how they would be used. More ideas about how to use lupin sprouts need to be promoted to increase the consumption of lupin sprouts.

Physically, the bean sprout consists of three distinct parts (the seed, the shoot and the root) and each of these can be taken into account when judgements are being made of sprout quality with mung sprouts.

Seed coat

After sprouting, the seed is reduced in size as it has provided the energy reserves required for the growth of the shoot. As a result of the sprouting process, the seed coat ruptures or splits and separates more or less completely from the seed. In the case of mung sprouts, the thin seed coat usually separates completely and is shed during the washing process. The seed coat of lupin is much harder and thicker and a large proportion of lupin sprouts still retains the seed coat even after the normal washing process has been completed.

It is not known whether or not, consumers prefer to have the seed coat attached to the sprout. It is possible that Caucasian consumers may prefer to eat the coat as a source of fibre whereas Asian consumers may prefer to eat sprouts without the seed coat because of their experiences. The preference results are shown in Figure 53.
Most consumers seemed to prefer the seed coat attached or said that they were indifferent to whether it is attached or not. This suggests that there is no need to remove any attached seed coats and that lupin sprouts would not be disadvantaged if many seed coats adhered to the grown sprout.

Sprout root

The root section of bean sprouts is a brown, thread like extension of the shoot which is not edible and can be regarded as unsightly if it is too long. Mung sprouts are usually sold with the root attached.

Preliminary evidence from the manufacturing stage of this research indicates that the root of the mung bean is proportionally longer than that of the lupin sprout. Hence any problems found with attached roots are more likely to apply to mung sprouts rather than lupin sprouts. It is not known whether, or not, consumers would prefer to have the root removed or left on the grown sprout. Preferences are shown in Figure 54.
Figure 54. Buying preferences: Root stem.

Most respondents would prefer that the root should be removed before purchase. This applied to both groups, but particularly to the Asian respondents. However, to remove the root before retail sale would increase the costs of producing bean sprouts. The easiest way to achieve this would be by snap harvesting during the final stage of production. This could be done much easier with lupin sprouts and so may be of some advantage when marketing the lupin sprouts. It should be noted however, that this was not regarded as a major consideration by most consumers.

Post-purchase consumer requirements

Respondents were asked a series of questions relating to the shelf life and storage of bean sprouts after buying.

Shelf life

Shelf life must be considered when examining those post-purchase factors which influence the behaviour of consumers. For example, mung sprouts are distributed to retail outlets about six days after germination. They then remain in the store for a further two to three days. The unsold sprouts are then discarded as waste. With this system, it is estimated that about 40 per cent of the harvested sprouts are lost.
Consumers were asked as to their perception of the optimum shelf life of sprouts. Answers to this question would throw some light on the suitability of the current distribution system for meeting the perceived needs of retail customers (see Appendix 9). The results are presented in Figure 55.

![Figure 55. Buying preferences: days old.](image)

The majority of the total group said that they would prefer to buy sprouts which are five days old, but more Asian respondents would like younger sprouts. It seems that most consumers would like sprouts to be younger than are currently available in retail stores. This may reflect a perception that some of the available sprouts appear to be more 'tired and wilted' than they would like. The evidence from this research shows that lupin sprouts mature earlier and last longer than do mung sprouts, and the answers to the above question are seen to favour lupin sprouts.

**Domestic storage of sprouts**

Little is known about how consumers handle and store sprouts after purchase. While most sprouts are sold at cool room temperature from the non refrigerated section of retail shops, it is not known whether the customer stores them in the refrigerator at home. According to Devereaux (1986), domestic refrigeration would extend the
shelf life of sprouts and similar fresh products, and this would be the better method of home storage. It may be that some consumers may see the sprout as a growing product and plant them to harvest at a later date as a truly fresh vegetable. Consumers were asked how they stored sprouts at home and the answers to this question are shown in Figure 56.

![Figure 56. Storage of sprouts after purchase.](image)

The vast majority of the consumers surveyed, store the sprouts in the domestic refrigerator. Very few hold them at room temperature or plant them in the garden. The domestic storage practices used by most consumers seem to be appropriate for this type of product.

**Final consumers of sprouts**

The development of a successful strategy for marketing fresh sprouts requires a knowledge of who in the family are the end users of sprouts. The women surveyed were most likely to be those who determined, and know the eating habits and preferences, of the various family members.
It is also likely that there will be marked cultural differences between the eating patterns and preferences of the two groups surveyed. It seems reasonable to predict that, as sprouts are a traditional food for Asian consumers, all family members will like and regularly eat sprouts. This may not be true for Caucasian families.

According to Wood (1985, p. 65), the family meal pattern today is often haphazard, chaotic and almost non-existent. The changing pattern of living is a major factor in determining Australian food patterns. Today, the number of families in which each parent has a career has risen, and thus Australian mothers have less time to prepare foods. For this reason, many Australian families make use of convenience and instant foods. Meal patterns have also changed; children arrive home from school alone and snack heavily to fill in time. What they eat will depend on the availability of the snack at home and their liking (Wood, 1985, p. 65).

Sprouts are perceived as a health food or as ‘good for you’ by health proponents (Wigmore, 1986, p. 36) Most young women are concerned about their eating habits, body weight and shape. To achieve desired goals several become vegetarian or partly vegetarian which restricts the range of meat in their diet. To balance the meal nutritionally, sprouts are considered as a meat alternative in combination with several other ingredients (Abraham, 1988, p. 92).

It is expected that, for South East Asians, all family members would eat sprouts as this is a cultural staple. From Caucasian respondents, adult females and children are now often expected to eat sprouts. The results of the question concerning the end users of sprouts by families, is shown in Table 16.

<table>
<thead>
<tr>
<th>Ethnic origin</th>
<th>Adult male %</th>
<th>Adult female %</th>
<th>Child male %</th>
<th>Child female %</th>
<th>Only adults %</th>
<th>Only female %</th>
<th>All %</th>
</tr>
</thead>
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<td>42</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>78</td>
</tr>
<tr>
<td>Combined</td>
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<td>14</td>
<td>1</td>
<td>0</td>
<td>11</td>
<td>4</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 16. Which of the family members eat sprouts
The results of this section of the survey showed that sprouts are most likely to be liked and eaten by adult females and, to a lesser extent, adult males in Caucasian culture. This indicates that there is an untouched market for sprout consumption. If sprouts are to be promoted for the domestic markets, then a strong promotional package is required to promote various uses of sprouts, especially as a snack by teenagers and children as an alternative to an existing snacking habit.

South East Asian respondents reported that all family members liked sprouts (80 percent) with virtually all adult females eating them. This was expected because of the meal pattern and food habits of these people.

Marketing efforts must be targeted at specific groups to change attitudes and behaviour and thus increase sprout consumption.

**Discussion**

When the respondents were asked to eat the two sprouts and compare them, the majority preferred the mung sprouts. While the appearance of the lupin sprouts was at least comparable to that of mung, this was not enough to outweigh the majority who preferred the taste and texture of mung sprouts.

The results of the consumer research component of this research indicates that there are relatively large differences between the Asian and Caucasian respondents as regards eating characteristics. While the Caucasian respondents were reasonably evenly divided in respect to preference, a strong majority of Asian respondents favoured the mung sprouts. This means that there are two distinct markets for bean sprouts and that lupin sprouts are more likely to be successful in the domestic Caucasian market than in the off-shore, Asian market.

Also, while most respondents recognized bean sprouts by name and by appearance when reminded, the unprompted recall rate for mung sprouts was very low compared with alfalfa and Brussel sprouts. This clearly reflects the lack of point-of-sale promotional material associated with the retailing of mung sprouts, and the generic
packaging used to present bean sprouts to retail customers. As most sales of sprouts take place in supermarkets, it seems that more energy should be put into promotion in supermarkets when marketing fresh sprouts. The end result of the present inadequate marketing effort, can be seen in the poor prices, unclear image and low rate of recall of the name of this valuable product.

To develop an effective strategy for marketing of bean sprouts, it is necessary to find out how consumers use this type of food. The results show that the most frequent use of sprouts is as a cooked ingredient in stir-fry dishes and as a fresh salad vegetable. However, there were large differences between Asians and Caucasians in the way the food is used. There were very few Asians who ate sprouts raw, with most using them as a stir-fry ingredient, while Caucasians used them as salad vegetables and snacks as well as a cooked food. The heaviest use of sprouts is in summer as a salad vegetable while they were used all year round as a cooked stir-fry ingredient.

An interesting finding was that Asian and Caucasian respondents gave quite different reasons for buying sprouts. The fact that sprouts are an integral, staple component of the daily diets of many Asian families is reflected in the emphasis that they place on the flavour of the sprouts. In contrast, the most important reason given by Caucasians for buying sprouts related to their nutritional value. This suggests that there are two distinct market segments to be serviced, and that an effective marketing strategy must take these differences into account.
Conclusions

In December, 1993 JAS introduced lupin sprouts in 11 retail outlets in the Perth metropolitan area. They received a good level of acceptance from Asian and Caucasian consumers. Lupin is not considered as a substitute for mung, but is recognized as a new line in the sprout market and fetched a higher retail price than mung. Currently, JAS grows only 80 to 100 kg of lupin sprouts per week, but expects to increase its production by late 1994. The introduction of a lupin-based value-added product such as lupin sprouts, into the market-place is the major direct commercial outcome of this research.

The main goal of the work, as determined by the hypothesis, was to determine if lupin sprouts could be satisfactorily produced under normal (factory) conditions. A major concern of the commercial producer was that it was essential that good quality lupin sprouts could be grown with minimum alterations to the existing facilities. This research showed that lupin sprouts could be grown in a commercial environment with only a few modifications to the existing procedures as used for the production of mung.

The existing conditions under which mung sprouts are grown at JAS are not quite suitable for the production of lupin sprouts. Some modifications to the present system are required, such as; change in seed batch size, water supply patterns during the growth period and washing procedures.

The existing chambers in which mung sprouts are grown have a floor area of 8 m². The batch size for mung is 100 kg of seed. Lupin seed generates more heat during the sprout growing cycle than mung and thus may provide a more favorable environment for the growth of spoilage microflora. A smaller lupin seed batch size for sprouts than that used for mung would be necessary and could be determined in further experiments. The existing watering pattern, as used for mung, is inadequate.
for the first two to three days of the lupin growing cycle because of the amount of heat generated. More frequent waterings of less quantity than that used for mung would be necessary for the first two or three days when growing lupin sprouts, but should revert to the current frequency for the last two or three days of sprouting.

Because this research was conducted during normal commercial operations, it was not possible to vary the test parameters so as to identify the optimal conditions for growing lupin sprouts. What can be said is that the existing equipment used for the washing of mung sprouts is not suitable for lupin sprouts. Modified equipment for spray washing would be needed and this could also be used for washing mung sprouts.

Lupin sprouts have no yield advantage (in weight gain multiples over its raw seed weight) compared with mung sprouts when both are grown under factory conditions. This finding is not in agreement with those of Yu et al. (1985). Lupin sprouts are whiter and have a more even shoot thickness than mung. This makes them superior to mung in appearance. The results prove that lupin sprouts could be produced commercially in an equivalent and consistent quality to that of mung sprouts.

There is a little difference in the microbial flora of the two products when grown under similar conditions. Both lupin and mung sprouts had no serious pathogenic problems such as Salmonella and E. coli. The research indicated that the environment at JAS was generally satisfactory and did not selectively facilitate the growth of pathogenic bacteria. However, this observation only applied to the tested batches and need not apply at all times. It is important that the seed batches in the production line be tested on a regular basis for the presence of harmful micro-organisms.

The test for non pathogenic bacteria showed that the sprouted mung seeds, sprouted lupin seeds and lupin shoots were all found to be contaminated with Pseudomonas fluorescences. Pseudomonads are very common in the natural environment and are no threat to the health of individuals. Lupin root and mung root are more sensitive to
Erwinia infection than other parts of the sprout, which causes a brown mush and foul odour. Lupin seed appears to be more susceptible to Erwinia infection than mung seed. This is because of external surface contamination rather than internal tissue infection. Contamination is greatest in the lupin seeds where the seed coat is still attached (may be loose) to the seed. The thicker seed coat in the case of lupin takes longer to shed and provides a pocket in which microbes may grow. Furthermore, the lupin seed coat does not disintegrate with the process of sprout maturation.

Lupin needs extra treatments to produce clean sprouts, such as; more chlorine in the irrigation water than mung, extra care in the washing of the seeds and the use of a surface decontaminant. The mechanical removal of the seed coat could improve the quality of lupin sprouts, but it would be an extra cost to the manufacturer and could be a tedious task to perform. More work is required to understand the presence of Erwinia and effect of Pseudomonas on the shelf life of sprouts. Such an investigation was not within the compass of this research programme.

The most important factor which makes lupin sprouts superior to mung is its low cost of manufacture. Lupin seeds are much cheaper than mung seed in Perth. Lupins are locally grown in Western Australia and the quality required for sprouting is easy to obtain. Mung, however, poses a problem for the sprout manufacturer because of dramatic changes in the price of raw seeds. It is difficult to obtain good quality mung seed for sprouting as the top quality seed is exported. The conversion of facilities to suit lupin production would not involve great cost. The modifications needed are more in respect to changing procedures such as watering patterns. The only equipment modification required is in the washing system, which could be designed to suit both mung and lupin. A preliminary cost analysis showed that lupin sprouts would have higher profits than mung sprouts. The best harvest day for lupin on the basis of appearance, length and weight is day 5, thus saving a day in the sprout growing cycle as used for mung. This makes lupins still more economical than mung and adds to the production capacity. The wastage rate remains the same in both
cases at about 20 per cent, and one layer of sprouts needs to be discarded in each case.

Another concern was whether commercially grown lupin sprouts would be an acceptable alternative or substitute to mung sprouts in the marketplace. The survey of sprout use showed that the lupin sprouts have a better potential as a new product rather than as a substitute for mung sprouts. This means that lupins could be successfully launched as a complementary sprout product to the existing sprout range.

South East Asians and Caucasians use sprouts in quite different ways. South East Asians use sprouts as a staple food and cooking ingredient, whereas Caucasians use them more as a health food in the form of a fresh vegetable for salad and for sandwiches. Mung sprouts, as a very familiar ingredient to Asians, attracts a better market with Asian consumers especially off-shore. Nevertheless, lupin show prospects in the domestic market with Caucasian consumers who are more likely to use lupin sprouts as a salad vegetable and snack. Subsequent observations, since the JAS introduction of lupin sprouts in Perth, have shown that the Asian consumers now purchase lupin sprouts as ‘big bean’ sprouts. This has important ramifications as it means that lupin seed may find a ready market in South East Asia for sprout production.

The packaging of mung sprouts is poor and inadequate for the development of a sizeable market for mung sprouts or lupins if used for that product. At present, mung sprouts are sold in open bags without proper packaging and without point of sale information material on the shelves. This method lacks marketing appeal. For these reasons, mung sprouts are unlikely to be a product that would attract new consumers. It is recommended that lupins for sale in the domestic market should be presented in prepacked containers with point of sale material at the retail counters. This could attract many consumers who may like to use lupin sprouts in salads or as a fresh vegetable.
In the final analysis, lupin sprouts can be grown commercially with a few modifications in the procedures used for the production of mung. Lupin is neither an alternative to nor a substitute for mung. Consumer research suggests that lupin could be successfully launched as a complementary product to the existing sprout range.

**Recommendations**

The following recommendations are made for the establishment of new locations or the modification of the existing commercial facilities, for the production of lupin sprouts.

- To achieve consistent quality, manufacturers should ensure that the first step of surface decontamination is regularly carried out. Seeds should be initially soaked in water containing an adequate level of surface decontaminant in accordance with the Campden Food and Drink Research Association recommendations of total chlorine of 100 to 200 ppm. Adequate contact time, the minimum recommended is 30 minutes, should be allowed for inactivation of the surface microflora. This time should be controlled and recorded. The Campden guidelines further recommend that the seeds should be drained and then rinsed until the water runs clear before soaking.

- The lupin sprout requirement for watering both in terms of quantity and frequency is different to mung. An independent watering system separate to that used for mung would be needed. Lupin should grow better with a variable water supply than one fixed for the whole growing cycle. It might need more frequent watering every two hours, on day 2 and day 3 and followed by four hourly watering for the rest of the cycle.

- Better environment controlled growing rooms with insulation, fans for ventilation, sensor lights for inspection, and an automatic door could improve sprout quality.
• Commercial batches of lupin can be grown. However, small batches of 3 kg raw seed is too small for commercial production and a batch of 100 kg raw seed is too large to give the required quality of sprouts. There is a relation between the surface area of the growth chamber and amount of seeds used which needs to be established. More work on batch size is required to determine the appropriate batch size for a particular facility.

• Lupin needs more water agitation while washing to remove all the seed coats. A system wherein water is sprayed with a needle-like fine pressure spray on the lupin to remove the remaining attached seed coats would be appropriate. If this is not possible, the manufacturer would have to provide for an extra labour cost of 25 per cent for washing lupin sprouts.

• A cooling system at the point of packaging which should be more than cold water, is required. A fan to cool down the sprouts before packaging would extend post-harvest shelf life.

Limitations of the research

The experiments were done in a commercially operating factory where the normal production schedule must continue. Under these circumstances, it was not possible to manipulate variables such as the room temperature or watering cycle in an orderly way. Such limitations would generally apply to any research conducted in a factory environment.

The price of lupin as a raw material can vary considerably between State and countries depending on supply and demand, transport costs, subsidies and other trade factors. Western Australia grows large amounts of lupins and little mung. As such, lupin enjoys a price advantage over mung as it is locally grown with low transportation costs to the manufacturer. In Queensland and New South Wales lupin may not have the same advantages as both lupin and mung are grown in these States.
Only one commercial factory was evaluated. Evaluation of other factories may produce more favourable results for lupin. Research in commercial facilities other than JAS is needed to test if lupin sprout production offers a profitable revenue for the potential investors.
References


-200-


Health Department of Western Australia (1992, May). *Western Australian Food Monitoring Program: Microbiological Quality of Salad in Western Australia*.


-203-


The Australian Horticultural Corporation (1989). *Changes in Export Forecasts are Damaging to Industry*.


Western Australian Food Monitoring Program (1992). Microbiological Quality of Salad in Western Australia available from Health Department of Western Australia.


Gram reaction

One of the most important distinguishing features of a bacterium is its reaction to a specific staining procedure named, after its Danish discover, the Gram stain (Hayes 1992 p. 4). By the use of this technique, bacteria can be divided into two types, Gram positive and Gram negative. The heat-fixed smear of bacteria, prepared on a glass slide, is stained with crystal violet (or other suitable basic dye). The smear is next treated with an iodine solution and then decolourized with alcohol. Gram positive bacteria retain the crystal violet whilst Gram negative bacteria are decolourized. By counter-staining the smear with a contrasting dye (e.g. carbol fuchsin, red) it is possible to readily distinguish the violet Gram positive forms from the red Gram negative forms. Although the staining technique was developed in the early 1880s the chemical basis of this differential reaction is still not fully understood, but the division of bacteria into these two groups correlates surprisingly well with many other characteristics (Hayes 1992, p. 5).
### APPENDIX 2

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Streak plate method

A sterile inoculation loop is dipped into a mixed culture that contains more than one type of microbe and is streaked in a pattern over the surface of the nutrient medium. The pattern as shown in Figure A5 is traced. As the pattern is traced, bacteria are rubbed off the loop onto the medium in paths of fewer and fewer cells. The last cell to be rubbed off the loop are far enough apart to grow into isolated colonies. This is incubated for 24 hours then checked for growth (Tortora, Funke and Case, 1989, p. 158).

Figure A5.

APPENDIX 6

Final report on laboratory submissions

Sample(s) submitted: Water x 1, lupin and mung bean sprouts

Bacteriology examination

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<tr>
<th>Sample</th>
<th>*CFU/GM Total count</th>
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<th>Salmonella</th>
<th>Listeria</th>
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<td>80,000,000</td>
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<tr>
<td>Lupin sprouts (A)</td>
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<td>48,000,000</td>
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* CFU/g = colony forming units/gram.
APPENDIX 7

Summary of quantitative results of consumer survey

### Appearance preference

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<td>47.71%</td>
<td>46.79%</td>
<td>5.50%</td>
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<td>S-E Asian</td>
<td>42.24%</td>
<td>44.83%</td>
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### Texture preference

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### Flavor preference

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### Over all preference

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### Combined responses

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### Use as a snack

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### APPENDIX 7 continued ...

#### Use as salad

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#### Use as stir-fry

<table>
<thead>
<tr>
<th>Country</th>
<th>Lupin</th>
<th>Mung</th>
<th>Both</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>37.61%</td>
<td>30.28%</td>
<td>27.52%</td>
<td>4.59%</td>
</tr>
<tr>
<td>Asia</td>
<td>14.78%</td>
<td>50.43%</td>
<td>33.91%</td>
<td>0.87%</td>
</tr>
<tr>
<td>Combined</td>
<td>26.20%</td>
<td>40.36%</td>
<td>30.72%</td>
<td>2.73%</td>
</tr>
</tbody>
</table>

#### Combined

<table>
<thead>
<tr>
<th></th>
<th>Lupin</th>
<th>Mung</th>
<th>Both</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snack</td>
<td>16.86%</td>
<td>23.30%</td>
<td>15.18%</td>
<td>44.66%</td>
</tr>
<tr>
<td>Sandwiches</td>
<td>10.94%</td>
<td>35.98%</td>
<td>13.02%</td>
<td>40.07%</td>
</tr>
<tr>
<td>Salad</td>
<td>15.75%</td>
<td>38.45%</td>
<td>25.29%</td>
<td>20.51%</td>
</tr>
<tr>
<td>Stir fry</td>
<td>26.20%</td>
<td>40.36%</td>
<td>30.72%</td>
<td>2.73%</td>
</tr>
</tbody>
</table>

#### Name of sprouts ever bought (recall - 1st name)

<table>
<thead>
<tr>
<th>Country</th>
<th>Mung</th>
<th>Alfalfa</th>
<th>Beans</th>
<th>Brussels</th>
<th>Others</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>5.50%</td>
<td>58.72%</td>
<td>5.50%</td>
<td>19.27%</td>
<td>6.42%</td>
<td>4.59%</td>
</tr>
<tr>
<td>Asia</td>
<td>8.62%</td>
<td>33.62%</td>
<td>7.76%</td>
<td>40.52%</td>
<td>4.31%</td>
<td>5.17%</td>
</tr>
<tr>
<td>Combined</td>
<td>7.06%</td>
<td>46.17%</td>
<td>6.63%</td>
<td>29.89%</td>
<td>5.37%</td>
<td>4.88%</td>
</tr>
</tbody>
</table>

#### Name of sprouts ever bought (recall - 2nd name)

<table>
<thead>
<tr>
<th>Country</th>
<th>Mung</th>
<th>Alfalfa</th>
<th>Beans</th>
<th>Brussels</th>
<th>Others</th>
<th>No answer/missing data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>10.09%</td>
<td>16.51%</td>
<td>22.02%</td>
<td>1.83%</td>
<td>9.17%</td>
<td>40.37%</td>
</tr>
<tr>
<td>Asia</td>
<td>3.45%</td>
<td>22.41%</td>
<td>20.69%</td>
<td>3.45%</td>
<td>3.45%</td>
<td>46.55%</td>
</tr>
<tr>
<td>Combined</td>
<td>6.77%</td>
<td>19.46%</td>
<td>21.35%</td>
<td>2.64%</td>
<td>6.31%</td>
<td>43.46%</td>
</tr>
</tbody>
</table>
APPENDIX 7 continued ...

Name of sprouts ever bought (recall - 3rd name)

<table>
<thead>
<tr>
<th>Country</th>
<th>Mung</th>
<th>Alfalfa</th>
<th>Beans</th>
<th>Brussels</th>
<th>Others</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>0.92%</td>
<td>1.83%</td>
<td>6.42%</td>
<td>3.67%</td>
<td>5.50%</td>
<td>81.65%</td>
</tr>
<tr>
<td>Asia</td>
<td>0.86%</td>
<td>1.72%</td>
<td>4.31%</td>
<td>4.31%</td>
<td>1.72%</td>
<td>91.38%</td>
</tr>
<tr>
<td>Combined</td>
<td>0.89%</td>
<td>1.78%</td>
<td>5.37%</td>
<td>3.99%</td>
<td>3.61%</td>
<td>86.52%</td>
</tr>
</tbody>
</table>

Name of sprouts ever bought (recall - 4th name)

<table>
<thead>
<tr>
<th>Country</th>
<th>Mung</th>
<th>Alfalfa</th>
<th>Beans</th>
<th>Brussels</th>
<th>Others</th>
<th>No answer/missing data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>0.00%</td>
<td>0.92%</td>
<td>0.00%</td>
<td>0.92%</td>
<td>1.83%</td>
<td>96.33%</td>
</tr>
<tr>
<td>Asia</td>
<td>0.86%</td>
<td>0.00%</td>
<td>0.86%</td>
<td>0.00%</td>
<td>0.86%</td>
<td>97.41%</td>
</tr>
<tr>
<td>Combined</td>
<td>0.43%</td>
<td>0.00%</td>
<td>0.43%</td>
<td>0.00%</td>
<td>0.43%</td>
<td></td>
</tr>
</tbody>
</table>

Name of sprouts ever bought

<table>
<thead>
<tr>
<th></th>
<th>1st recall</th>
<th>2nd recall</th>
<th>3rd recall</th>
<th>4th recall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alfalfa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>58.72%</td>
<td>16.51%</td>
<td>1.83%</td>
<td>0.92%</td>
</tr>
<tr>
<td>Asia</td>
<td>33.62%</td>
<td>22.41%</td>
<td>1.72%</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>Mung</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>5.50%</td>
<td>10.09%</td>
<td>0.92%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Asia</td>
<td>8.62%</td>
<td>3.45%</td>
<td>0.86%</td>
<td>0.86%</td>
</tr>
<tr>
<td><strong>Beans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>5.50%</td>
<td>22.02%</td>
<td>6.42%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Asia</td>
<td>7.76%</td>
<td>20.69%</td>
<td>4.31%</td>
<td>0.86%</td>
</tr>
<tr>
<td><strong>Brussels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>19.27%</td>
<td>1.83%</td>
<td>3.67%</td>
<td>0.92%</td>
</tr>
<tr>
<td>Asia</td>
<td>40.52%</td>
<td>3.45%</td>
<td>4.31%</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>6.42%</td>
<td>9.17%</td>
<td>5.50%</td>
<td>1.83%</td>
</tr>
<tr>
<td>Asia</td>
<td>4.31%</td>
<td>3.45%</td>
<td>1.72%</td>
<td>0.86%</td>
</tr>
<tr>
<td><strong>No answer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>4.59%</td>
<td>40.37%</td>
<td>81.65%</td>
<td>96.33%</td>
</tr>
<tr>
<td>Asia</td>
<td>5.17%</td>
<td>46.55%</td>
<td>91.38%</td>
<td>97.41%</td>
</tr>
</tbody>
</table>
APPENDIX 7 continued ...

Have you ever bought mung?

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>44.04%</td>
<td>44.04%</td>
<td>10.09%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>40.52%</td>
<td>47.41%</td>
<td>10.34%</td>
</tr>
<tr>
<td>Combined</td>
<td>42.28%</td>
<td>45.73%</td>
<td>10.22%</td>
</tr>
</tbody>
</table>

Have you ever bought alfalfa?

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>93.58%</td>
<td>6.42%</td>
<td>0.00%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>79.31%</td>
<td>19.83%</td>
<td>0.86%</td>
</tr>
<tr>
<td>Combined</td>
<td>86.44%</td>
<td>13.12%</td>
<td>0.43%</td>
</tr>
</tbody>
</table>

Have you ever bought lupin?

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>5.61%</td>
<td>84.40%</td>
<td>8.57%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>0.00%</td>
<td>84.35%</td>
<td>15.65%</td>
</tr>
<tr>
<td>Combined</td>
<td>2.80%</td>
<td>84.38%</td>
<td>12.11%</td>
</tr>
</tbody>
</table>

Mung: Loose/in punnet?

<table>
<thead>
<tr>
<th>Country</th>
<th>Loose</th>
<th>In Punnet</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>27.52%</td>
<td>16.51%</td>
<td>10.09%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>40.52%</td>
<td>0.86%</td>
<td>55.17%</td>
</tr>
<tr>
<td>Combined</td>
<td>34.02%</td>
<td>8.69%</td>
<td>32.63%</td>
</tr>
</tbody>
</table>

Alfalfa: Loose/in punnet?

<table>
<thead>
<tr>
<th>Country</th>
<th>Loose</th>
<th>In Punnet</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>6.42%</td>
<td>36.24%</td>
<td>2.75%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>18.10%</td>
<td>60.34%</td>
<td>18.97%</td>
</tr>
<tr>
<td>Combined</td>
<td>12.26%</td>
<td>73.29%</td>
<td>10.86%</td>
</tr>
</tbody>
</table>

Lupin: Loose/in punnet?

<table>
<thead>
<tr>
<th>Country</th>
<th>Loose</th>
<th>In punnet</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>1.94%</td>
<td>3.88%</td>
<td>94.17%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>0.00%</td>
<td>2.68%</td>
<td>97.32%</td>
</tr>
<tr>
<td>Combined</td>
<td>0.97%</td>
<td>3.28%</td>
<td>95.75%</td>
</tr>
</tbody>
</table>
### APPENDIX 7 continued ...

#### Order of importance - nutrition

<table>
<thead>
<tr>
<th>Country</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>50.47%</td>
<td>28.97%</td>
<td>16.82%</td>
<td>3.74%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>22.81%</td>
<td>34.21%</td>
<td>32.46%</td>
<td>10.53%</td>
</tr>
<tr>
<td>Combined</td>
<td>36.64%</td>
<td>31.59%</td>
<td>24.64%</td>
<td>7.13%</td>
</tr>
</tbody>
</table>

#### Order of importance - price

<table>
<thead>
<tr>
<th>Country</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>6.73%</td>
<td>10.58%</td>
<td>27.88%</td>
<td>51.92%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>7.96%</td>
<td>33.63%</td>
<td>33.63%</td>
<td>24.78%</td>
</tr>
<tr>
<td>Combined</td>
<td>7.35%</td>
<td>22.10%</td>
<td>30.76%</td>
<td>38.35%</td>
</tr>
</tbody>
</table>

#### Order of importance - taste

<table>
<thead>
<tr>
<th>Country</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>20.75%</td>
<td>40.57%</td>
<td>29.25%</td>
<td>9.43%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>64.60%</td>
<td>21.24%</td>
<td>11.50%</td>
<td>2.65%</td>
</tr>
<tr>
<td>Combined</td>
<td>42.68%</td>
<td>30.90%</td>
<td>20.37%</td>
<td>6.04%</td>
</tr>
</tbody>
</table>

#### Order of importance - change/variety

<table>
<thead>
<tr>
<th>Country</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>23.81%</td>
<td>20.00%</td>
<td>27.62%</td>
<td>28.57%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>5.61%</td>
<td>12.15%</td>
<td>23.36%</td>
<td>58.88%</td>
</tr>
<tr>
<td>Combined</td>
<td>14.71%</td>
<td>16.07%</td>
<td>25.49%</td>
<td>43.72%</td>
</tr>
</tbody>
</table>

#### Buying preference: Seed coat

<table>
<thead>
<tr>
<th>Country</th>
<th>On</th>
<th>Off</th>
<th>Either</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>43.12%</td>
<td>24.77%</td>
<td>32.11%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>43.10%</td>
<td>29.31%</td>
<td>27.59%</td>
</tr>
<tr>
<td>Combined</td>
<td>43.11%</td>
<td>27.04%</td>
<td>29.85%</td>
</tr>
</tbody>
</table>

#### Buying preference: Days old

<table>
<thead>
<tr>
<th>Country</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>10.09%</td>
<td>11.93%</td>
<td>11.01%</td>
<td>11.93%</td>
<td>48.62%</td>
<td>4.59%</td>
<td>0.00%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>17.24%</td>
<td>12.07%</td>
<td>18.97%</td>
<td>14.66%</td>
<td>32.76%</td>
<td>0.00%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Combined</td>
<td>13.67%</td>
<td>12.00%</td>
<td>14.99%</td>
<td>13.29%</td>
<td>40.69%</td>
<td>2.29%</td>
<td>1.29%</td>
</tr>
</tbody>
</table>
### Buying preference: Root stem

<table>
<thead>
<tr>
<th>Country</th>
<th>On</th>
<th>Off</th>
<th>Either</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>23.85%</td>
<td>47.71%</td>
<td>28.44%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>18.10%</td>
<td>69.83%</td>
<td>21.55%</td>
</tr>
<tr>
<td>Combined</td>
<td>20.98%</td>
<td>58.77%</td>
<td>25.00%</td>
</tr>
</tbody>
</table>

### Where would you be more likely to keep sprouts in the home

<table>
<thead>
<tr>
<th></th>
<th>Fridge</th>
<th>Shelf</th>
<th>Outside</th>
<th>Do not store</th>
<th>Window sill</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of respondents</td>
<td>89.59%</td>
<td>7.24%</td>
<td>1.81%</td>
<td>0.90%</td>
<td>0.45%</td>
</tr>
</tbody>
</table>

### Age distribution

<table>
<thead>
<tr>
<th>Country</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>29.36%</td>
<td>18.35%</td>
<td>29.36%</td>
<td>22.94%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>33.91%</td>
<td>26.96%</td>
<td>24.35%</td>
<td>14.78%</td>
</tr>
<tr>
<td>Combined</td>
<td>31.64%</td>
<td>22.65%</td>
<td>26.85%</td>
<td>18.86%</td>
</tr>
</tbody>
</table>

### Where have you bought sprouts

<table>
<thead>
<tr>
<th>Country</th>
<th>S-Mark</th>
<th>Fruit</th>
<th>Health shop</th>
<th>Chinese</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>72</td>
<td>46</td>
<td>7</td>
<td>1</td>
<td>126</td>
</tr>
<tr>
<td>Asia</td>
<td>83</td>
<td>31</td>
<td>6</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>Combined</td>
<td>155</td>
<td>77</td>
<td>13</td>
<td>31</td>
<td>276</td>
</tr>
</tbody>
</table>

### Use of sprouts in summer as or in:

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Snack</td>
<td></td>
</tr>
<tr>
<td>18.22%</td>
<td>81.78%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Use of sprouts in winter as or in:

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Snack</td>
<td></td>
</tr>
<tr>
<td>12.44%</td>
<td>87.56%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Use of sprouts in:

<table>
<thead>
<tr>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snake</td>
<td>Salad</td>
</tr>
<tr>
<td>18.22%</td>
<td>58.67%</td>
</tr>
<tr>
<td>12.44%</td>
<td>24.89%</td>
</tr>
</tbody>
</table>
APPENDIX 7 continued ...

Would you buy: Photo A - p. 153

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>22.58%</td>
<td>64.52%</td>
<td>12.90%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>22.12%</td>
<td>68.27%</td>
<td>9.62%</td>
</tr>
<tr>
<td>Combined</td>
<td>22.35%</td>
<td>66.39%</td>
<td>11.26%</td>
</tr>
</tbody>
</table>

Would you buy: Photo B - p. 153

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>92.52%</td>
<td>7.48%</td>
<td>0.00%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>65.79%</td>
<td>28.95%</td>
<td>5.26%</td>
</tr>
<tr>
<td>Combined</td>
<td>79.16%</td>
<td>18.21%</td>
<td>2.63%</td>
</tr>
</tbody>
</table>

Would you buy: Photo C - p. 153

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>78.10%</td>
<td>20.00%</td>
<td>1.90%</td>
</tr>
<tr>
<td>S-E Asian</td>
<td>92.11%</td>
<td>5.26%</td>
<td>2.63%</td>
</tr>
<tr>
<td>Combined</td>
<td>85.10%</td>
<td>12.63%</td>
<td>2.27%</td>
</tr>
</tbody>
</table>

Would you buy: % of total respondents

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo A</td>
<td>22.35%</td>
<td>66.39%</td>
<td>11.26%</td>
</tr>
<tr>
<td>Photo B</td>
<td>79.16%</td>
<td>18.21%</td>
<td>2.63%</td>
</tr>
<tr>
<td>Photo C</td>
<td>85.10%</td>
<td>12.63%</td>
<td>2.27%</td>
</tr>
</tbody>
</table>

Which of the family members eat sprouts?

<table>
<thead>
<tr>
<th>Country</th>
<th>Adult male</th>
<th>Adult female</th>
<th>Child male</th>
<th>Child female</th>
<th>Only adults</th>
<th>Only female</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>3.67%</td>
<td>17.43%</td>
<td>1.83%</td>
<td>0.92%</td>
<td>18.35%</td>
<td>5.50%</td>
<td>42.20%</td>
</tr>
<tr>
<td>Asia</td>
<td>0.86%</td>
<td>10.34%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>3.45%</td>
<td>3.45%</td>
<td>78.45%</td>
</tr>
<tr>
<td>Combined</td>
<td>2.27%</td>
<td>13.89%</td>
<td>0.92%</td>
<td>0.46%</td>
<td>10.90%</td>
<td>4.48%</td>
<td>60.33%</td>
</tr>
</tbody>
</table>

Where you bought sprouts

<table>
<thead>
<tr>
<th>Country</th>
<th>Supermarket</th>
<th>Fruit shop</th>
<th>Health shop</th>
<th>Gourmet shop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>69.23%</td>
<td>44.23%</td>
<td>6.73%</td>
<td>0.96%</td>
</tr>
<tr>
<td>Asia</td>
<td>73.45%</td>
<td>27.43%</td>
<td>5.31%</td>
<td>26.55%</td>
</tr>
<tr>
<td>Combined</td>
<td>71.43%</td>
<td>35.48%</td>
<td>5.99%</td>
<td>14.29%</td>
</tr>
</tbody>
</table>
## APPENDIX 8

### Comparing shelf life

Results of shelf life observations on mung and lupin sprouts

<table>
<thead>
<tr>
<th>Observation time</th>
<th>Room temperature</th>
<th>Cool room</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mung</td>
<td>Lupin</td>
</tr>
<tr>
<td>Appearance and texture immediately after harvest</td>
<td>Shoot white and moist, long roots. Colour of root and shoot are same, leaves are green. Overall appearance fresh and good. Very crisp.</td>
<td>Shoot white and moist, roots are smaller than mung, no leaves. Very crisp.</td>
</tr>
<tr>
<td>After three hours</td>
<td>Good. Shoot white and moist, leaves are green. Crisp</td>
<td>Good. Roots are smaller than mung. Leaves are green. Crisp</td>
</tr>
<tr>
<td>Storage appearance and texture</td>
<td>Appearance good, shoot and root are white, leaves drying crisp, but less than previous sample.</td>
<td>Appearance good, shoot and root are white. Crisp.</td>
</tr>
<tr>
<td>Six hours</td>
<td>Appearance good, shoot and root are white, leaves drying crisp, but less than previous sample.</td>
<td>Appearance good, shoot and root are white. Crisp.</td>
</tr>
<tr>
<td>Twelve hours</td>
<td>Appearance, looks old, shoot was darkened. Root was wilting. Not crisp.</td>
<td>Appearance less attractive. Shoot and root still moist, root is bit darkened in colour. Still crisp.</td>
</tr>
<tr>
<td>One day</td>
<td>Appearance is not attractive. Shoot is brown, root has lost all moisture, not crisp. This will not be acceptable to consumer hence can not sell at any price.</td>
<td>Appearance is less attractive. Shoot is changing colour, but still moist, root getting darker. Much less crisp than previous sample.</td>
</tr>
<tr>
<td>Two day</td>
<td>Loss of moisture from shoot and root, looks like pieces of cotton (threads), although no fungal growth and no foul smell.</td>
<td>Shoot has turned brownish, but still moist. Root is brown. Lost crispness, no fungus but off odour.</td>
</tr>
</tbody>
</table>
APPENDIX 9

Existing distribution channel for sprouts

1

Sprout Manufacturer

\[\downarrow\]

Central supermarket chain

\[\downarrow\]

Individual supermarket

\[\downarrow\]

Consumer

2

Sprout manufacturer

\[\downarrow\]

Individual fruit and vegetable shops

\[\downarrow\]

Consumer
Recent developments in protein quality evaluation

E. Boutrif
Dr. E. Boutrif is Senior Officer, Food Quality and Consumer Protection Group, Food Policy and Nutrition Division, FAO, Rome.

Proteins are not alike. They vary according to their origin (animal, vegetable), their amino acid composition (particularly their relative content of essential amino acids), their digestibility, texture, etc. Good quality proteins are those that are readily digestible and contain the essential amino acids in quantities that correspond to human requirements.

Humans require certain minimal quantities of essential amino acids from a biologically available source as part of a larger protein/nitrogen intake. The required amounts of these amino acids vary with age, physiological condition and state of health. It is therefore important to be able to discriminate with both accuracy and precision the relative efficiency with which individual protein sources can meet human biological needs. This efficiency also has direct implications for the commercial value of the protein product.

Clinical human studies that measure growth and/or other metabolic indicators provide the most accurate assessment of protein quality. For reasons of both cost and ethics, such techniques cannot be used. Consequently, assay techniques designed to measure the effectiveness of a protein in promoting animal growth have been utilized. Since 1919, the protein efficiency ratio (PER) method, which measures the ability of a protein to support growth in young, rapidly growing rats, has been used in many countries because it was believed to be the best predictor of clinical tests. However, after decades of use, it is now recognized that PER overestimates the value of some animal proteins for human growth while it underestimates the value of some vegetable proteins for that purpose. The rapid growth of rats (which increases the need for essential amino acids) in comparison to human growth rates is the reason for this discrepancy.

For some time the use of an amino acid score has been advocated as an alternative to the PER. Although clearly the quality of some proteins can be assessed directly by using amino acid score values, that of others cannot.
because of poor digestibility and/or bioavailability. Consequently, both amino acid composition and digestibility measurements are considered necessary to predict accurately the protein quality of foods for human diets.

On the other hand, the methods currently used for measuring protein quality of foods were established when information was not extensively available on human amino acid requirements. Therefore, while results were not grossly in error, they did not accurately reflect human requirements. Since most of these methods use a rat assay, they in large part measure the amino acid requirements of the rat rather than the human. This is particularly misleading, since the rat appears to have a much higher requirement for sulfur amino acids than the human (see Table). In addition to the higher requirement for sulfur amino acids, the rat also has a higher requirement for histidine, threonine, and valine.

**NEED FOR INTERNATIONALLY STANDARDIZED PROCEDURE**

The Codex Committee on Vegetable Proteins (CCVP), while elaborating general guidelines for the utilization of vegetable protein products in foods, felt the need for a suitable indicator to express protein quality. It pointed out...
at its first session in 1980 that PER might not be the most suitable means for protein quality evaluation. In the successive two sessions, the committee considered the suitability of other indicators such as the relative net protein ratio (RNR) (a rat assay procedure) and the amino acid composition data (amino acid scores) corrected for crude protein digestibility/amino acid availability, but no decision was taken. At its fourth session (Havana, 2 to 6 February 1987), the committee noted improvements made in amino acid analysis and amino acid requirement pattern and discussed initial data from ongoing comparative studies organized by the United States Department of Agriculture (USDA) involving amino acid availability, nitrogen digestibility and protein nutritional assessment based on amino acid composition data. The committee concluded that an amino acid scoring procedure, corrected for true digestibility of protein and/or bioavailability of limiting amino acids, is the preferred approach for assessing protein quality of vegetable protein products and other food products. The results of the collaborative studies undertaken on the subject in 1987 and 1988 (Bodwell, Carpenter and McDonough, 1989; McDonough et al., 1990) and recent improvements in amino acid methodology enable the committee at its fifth session (Ottawa, 6 to 10 February 1989) to endorse the use of the FAO/WHO/UNU (1985) suggested pattern of amino acid requirements of a two- to five-year-old child as the reference for calculating amino acid scores. The committee agreed that amino acid scoring (based on the amount of the single most limiting amino acid) corrected for true digestibility of protein (as determined by the rat balance method) is the most suitable routine method for assessing the protein quality of most vegetable protein products and other food products (Codex Alimentarius Commission, 1989). Because the methodology used to measure protein quality had broad implications beyond its purview, the CCVP recognized the need for the wider scientific community to address issues such as human requirements for essential amino acids, amino acid evaluation methodology, protein digestibility and amino acid availability. The committee accordingly recommended that a Joint FAO/WHO Expert Consultation should be held to review the issues. The Joint FAO/WHO Expert Consultation on Protein Quality Evaluation was held in Bethesda, Maryland, USA from 4 to 8 December 1989.

**JOINT FAO/WHO EXPERT CONSULTATION ON PROTEIN QUALITY EVALUATION**

The consultation was convened for the task of:

- reviewing present knowledge of protein quality evaluation;
- discussing various techniques used in evaluating protein quality;
- specifically evaluating the method recommended by the CCVP, i.e. amino acid score corrected for digestibility.

The consultation reviewed in particular the scientific basis for the adoption of the protein digestibility-corrected amino acid score method. It recognized that the most tenacious problem with the use of a rat growth assay in predicting protein quality in food is that rats have a higher requirement than humans for some amino acids. The PER is the official method for assessing protein quality of foods in Canada and the United States, but it has been severely criticized for not meeting the criteria for a valid routine test (Sanver and McDonough, 1990). A major criticism of the PER assay is that it does not properly credit protein used for maintenance purposes. A protein source may not support growth and may have a PER near zero yet may still be adequate for maintenance purposes. Because of the error introduced by not making allowance for maintenance, PER values are not proportional to protein quality. i.e. a PER of 2.0 cannot be assumed to be twice as good as a PER of 1.0. The lack of proportionality of protein quality makes the PER method unsuitable for the calculation of utilizable protein, as in protein rating (protein in a reasonable daily intake, mass x PER).

The nutritive value of a protein depends upon its capacity to provide nitrogen and amino acids in adequate amounts to meet the requirements of an organism. Thus, in theory the most logical approach for evaluating protein quality is to compare amino acid content (taking bioavailability into account) of a food with human amino acid requirements. A number of comparisons have been made using reference patterns such as those derived from egg and milk protein. The first major change in procedure was substitution of a provisional pattern of amino acid requirements for the egg protein standard.

A hypothetical reference protein derived from the pattern of human amino acid requirements was proposed as a standard for comparison. Shortcomings have been recognized and progress has been made in accurately evaluating human amino acid requirements. Equally critical for success is the ability to obtain precise
measurements of amino acid content in the protein sources. Finally, to improve on accuracy of scoring procedures, chemically determined amino acid contents may have to be corrected for digestibility or biological availability.

Conclusions and recommendations

Methodology for determining the amino acid composition of proteins. The consultation concluded that modern amino acid analysis can provide data with a repeatability within a laboratory of about 5 percent and a reproducibility between laboratories of about 10 percent. It recommended that this variability be considered acceptable for the purposes of calculating amino acid score. To achieve such results requires careful attention to many aspects of the protocols, including replicating the complete analytical procedure. The consultation also made the following recommendations:

• Further studies should be undertaken to standardize the hydrolytic and oxidation procedures and improve accuracy of the procedures to further reduce interlaboratory variation.
• Amino acid data should be reported as mg amino acid per g N or be converted to mg amino acid per g protein by use of the factor 6.25. No other foodspecific protein factor should be used.
• FAO should update their publication Amino acid content of foods and biological data on proteins (FAO, 1970) and commission new analyses of foods where there are insufficient reliable data.
• Reliable national tables of amino acid composition of products that have been clearly defined in terms of composition and processing should be developed.

Amino acid scoring pattern. The consultation evaluated the existing evidence and arguments about the use of amino acid scoring patterns to evaluate protein quality and concluded that at present there is no adequate basis for the use of different scoring patterns for different age groups with the exception of infants. Therefore, it decided to make the following recommendations:

• The amino acid composition of human milk should be the basis of the scoring pattern to evaluate protein quality in foods for infants under one year of age.
• The amino acid scoring pattern proposed by FAO/WHO/UNU (1985) for children of preschool age should be used to evaluate dietary protein quality for all age groups except infants.

• The recommendations made here for the two amino acid scoring patterns to be used for infants and for all other ages must be deemed as temporary until the results of further research either confirm their adequacy or demand a revision.

• Further research must be carried out to confirm the currently accepted values of requirements of infants, and preschool-aged children, which are the basis for the scoring patterns recommended by this consultation.

• Further research must be carried out to define the indispensable amino acids (IAA) requirements of school-aged and adolescent children and of adults.

• Given the urgency of these research needs and the magnitude of the task required, it is recommended that an FAO/WHO coordinated international research programme be established immediately to assist in the determination of human amino acid needs.

Digestibility of proteins. The consultation discussed in detail the various methods used for determining the digestibility of proteins and made the following recommendations:

• Studies should be undertaken to compare protein digestibility values of humans and rats from identical food products.
• Extensive evaluation of existing in vitro and in vivo methods in foods indicates that the rat balance method is the most suitable practical method for predicting protein digestibility by humans. Therefore, when human balance studies cannot be used, the standardized rat fecal-balance method of Eggum (1973) or McDonough et al. (1990) is recommended.
• Since the true digestibility of crude protein is a reasonable approximation of the true digestibility of most amino acids (as determined by the rat balance method), it is recommended that amino acid scores be corrected only for true digestibility at protein.
• For new or novel products or processes, digestibility values must be determined. However, established digestibility values of well-defined foods may be taken from a published data base for use in the amino acid scoring procedure. A data base should

\[
A = \frac{1}{1-f(R-Pr)}
\]

where \(A\) = absorbed nitrogen, \(R\) = total nitrogen, \(Pr\) = metabolic nitrogen and \(f\) = nitrogen intake.

"
be established for raw and processed products. Further research is encouraged to perfect and evaluate the most promising in vitro procedures for estimating protein digestibility, such as those of Samelis, Marshall and Tennyson (1979) and Pedersen and Eggum (1983).

Based on the above conclusions, the consultation agreed that the protein digestibility-corrected amino acid score method was the most suitable approach for routine evaluation of protein quality for humans and recommended that it be adopted as an official method at the international level.

The report of the consultation contains details of the recommended methodology for the evaluation of protein quality and a practical guide on how to apply this methodology for individual foods as well as food mixes. Copies of the report may be obtained on request from the author.

REFERENCES


