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Effects of food gums and pre-drying on fat content of fabricated fried chips

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Abstract

Deep frying contributes to the unique taste and texture of fried products. However, they are low in nutritional value. Food industries actively trying to find ways to reduce the fat content while maintaining organoleptic properties of fried foods. In this work, effects of pre-drying and adding food gums on the moisture and fat contents of chips were evaluated. The chips were pre-dried for 60 and 90 min and gellan gum, guar gum, methylcellulose and xanthan gum, were added at the concentration of 0.25, 0.75, 1 and 2 % w/w. The xanthan gum was the most effective gum for fat reduction. The addition of 0.25 % w/w xanthan gum and at 90 min pre-drying reduced the fat

content from 20 % (control)to 15 % w/w. The results also indicated that the reduction of moisture content after frying was not affected by the type of gums but the method of pre-drying.

Introduction

Deep frying is widely used in the food industry to produce a range of food products with high consumer acceptability. Fried foods commonly high in fat content contributes to the distinctive flavour and better texture profile that can only be achieved by deep-frying (Kurek *et al.,* 2017). The development of the porous crust where most oil adheres is associated with improving the crispy texture of fried food (Lumanlan *et al.,* 2020). These favourable characteristics have corresponded to their popularity and higher sales all over the world. Commercial fried chips low in nutrition and fat content up to 40 % are becoming a concern with human health and wellbeing (Southern *et al.,* 2000; Saguy & Dana, 2003). Particularly, obesity, cardiovascular and Alzheimer's disease are correlated with the high-fat diets (Martins & Fernando, 2014; Mann & McLean, 2017). These health risks have led the food industries for decades to reduce the fat content of fried chips while retaining the favourable characteristics.

Some food gums exhibit thermo-gelling properties when heated and forms a film barrier reducing oil uptake. For instance, incorporating food gums into the batter formulation reduced the oil content of potato products by 84 % (Mallikarjunan *et al.,* 1997), and 0.50 % (w/v) guar gum reduced fat content by 53 % of fried carrots (Akdeniz *et al.,* 2006). The formation of the film during deep frying of potato chips with 1 % (w/v) xanthan gum reduced the oil absorption by 50 % (Garmakhany *et al.,* 2008), and guar gum solutions reduced the oil content up to 40 % (Kim *et al.,* 2011). Furthermore, food gums were added to chickpea flour to produce fried sev. Bajaj & Singhal (2007) found a 32 % fat reduction with 0.75 % (w/w) gellan gum, and 15 % fat reduction with 0.5 % (w/w) guar gum (Annapure *et al.,* 1999). Different applications and effects of food gums in reducing oil uptake could be due to the film that was formed depending on the gum concentrations level and food properties.

The amount of food moisture during deep-frying was found to be associated with fat content (Duran *et al.,* 2007; Moreira *et al.,* 1997). Reducing the food moisture content by oven drying can reduce oil absorption by up to 54 % (Debnath *et al.,* 2003) because the quantity of water removed by pre-drying, could decrease the gradient of water –oil transfer.

Previous reports did not investigate combining food gums and pre-drying treatments in reducing oil uptake during deep frying of chips (Mallikarjunan *et al.,* 1997; William & Mittal, 1999; Garcia *et al.,* 2002; Bajaj & Singhal, 2007; Akdeniz *et al.,* 2006; Garmakhany *et al.,* 2008; Moreno *et al.,* 2010). However, paper published by Lumanlan *et al.* (2020) indicated that reducing the moisture content and the addition of food gums before deep-frying could lead to fat reduction and improve food quality, such as crispiness on some fried foods.

The global concern in the health and well-being due to poor diet has led food industries to lower fat content and imcrease the protein, dietary fibre and bioactive compounds to meet consumers demand. The addition of lupin flour in some food products such as instant noodles and bakery products have successfully increased dietary fibre from 2 to 32 % and protein from 2 to 41 % (Jayasena & Nassar Abbas, 2011; Nassar Abbas & Jayasena, 2012; Rumiyati, *et al.,* 2015; Villarino *et al.,* 2014). Moreover, the non-starchy grain legume lupin low in fat content, high protein and dietary fibre can lower blood cholesterol, protection from colon cancer, lower the risk of obesity or overweight and maintains long term health (Jayasena & Nassar Abbas, 2010; Khan *et al.,* 2015; Rumiyati, *et al.,* 2013). The study carried out incorporating lupin flour, different food gum concentrations, and pre-drying chips for the purpose of reducing the fat content has not been reported. Thus, this study investigated the effects of gellan gum, guar gum, methylcellulose and xanthan gum and pre-drying treatment on moisture and fat contents of fried chips.

Keywords: Food gums, pre-drying, moisture content, fat content, fat reduction, deep-frying

Materials and Method

Materials

Commercial potato flakes were purchased from Scalzo Food Industries in Melbourne, Australia. Lupin flour (Lupinus angustifolius L.) was purchased from Irwin valley milling, Western Australia. Sodium bicarbonate (baking soda) manufactured by McKenzies was purchased from the local store. Commercial gellan gum powder (E 418) and methylcellulose powder (E 461) were purchased from Melbourne Food Depot; guar gum (E 412) and xanthan gum (E 415) were purchased from Lotus Pantry Sydney.

Fabricated chips production process

Control fabricated chips formulation consisted of potato flakes, lupin flour, baking soda and water. Food gums were added at 0.25, 0.75, 1 and 2 % w/w to the control formulation (Table 1).

Table 1. Fabricated chips with type of food gums and concentrations

Potato flakes, lupin flour, baking powder and food gums were individually weighed (Mettler Toledo digital scale Model TLE3002) and placed in a metal bowl. All dry ingredients with an average weight of 500 g were blended for 40 s (Optimum electric blender Model no. G2.3) and were transferred in Bottene pasta extruder (Model Inver 3T) with a disc attachment (0.8 cm width x 1 mm thickness). The dough was developed while water was added gradually, mixing for 15 min, the extruded intermediate productwere cut to approximately 6 cm long using automatic cutter attachment.

Pre-drying of intermediate products

Labec oven dryer (Model ODWTF50-SD) was set at 55 ± 5 °C. Approximately 70 g intermediate products were placed on a 39 x 26 cm metal tray, and samples with different food gums (gellan gum, guar gum, methylcellulose and xanthan gum), and concentrations (0.25, 0.75, 1 and 2 % w/w) were dried for 60 and 90 min.

Deep frying

The Kambrook deep fryer (Model KDF560) filled with 3.5 litres of canola oil (Goodman Fielder, Sydney) was preheated until up to 170 °C. This temperature was maintained throughout the process. The oil temperature was checked continuously using an Acurite digital cooking thermometer (Model 00277DIX). Samples (~30 g) were deep-fried for 30 s. Immediately after deep frying, samples were transferred on trays (39 x 26 cm) lined with an absorbent paper. After 60 min cooling period, samples were placed into polypropylene bags (Hercules resealable storage bag) and stored in a cool room (4 - 5 °C) to protect from moisture and environmental factors until further test.

Determination of moisture content

Samples were grinded for 20 s (Optimum electric blender Model no. G2.3), and weighed using an analytical balance (Mettler Toledo Model TLE204). Around 1.5 g samples were placed into a heat resistant ANKOM XT filter bag and heat-sealed (Impulse sealer Type: AIE-200-2). The samples were placed in the Heratherm drying oven (Model OMS100) at 100 °C and dried for 24 h method 990.19 (AOAC, 2007). A metal tong was used to handle samples to avoid moisture from fingers adding to the weight. After drying, the samples were placed in desiccators for 30 min for cooling before weight was recorded.

Determination of fat content

Soxhlet Fat Extractor (Model BUCHI 810) was used for fat extraction. AOAC (2009) method 960.39 was used to determine the fat content of samples. Each sample weighed approximately 1.5 g was placed into extraction chambers. Petroleum ether (BR 40-70, UNILAB) heated at 154°C for 2 h was used to extract the fats. After fat extraction, the residual solvent was dried by placing samples in Heratherm drying oven (Model OMS100) at 100 ºC for 1 h method 990.19 (AOAC, 2007). Desiccator was used to cool samples for 30 mins before recording the weight.

Percentage change in fat content

The change in fat content (% db) compared to the control was calculated using Equation 1.

$$C_F = \frac{F_c - F_t}{F_c} \text{ x } 100 \qquad (1)$$

Where

C_f = Change in fat content (% db) compare to the control

F_c = Fat content of the control

F_t = Fat content with food gums and pre-drying treatments

Statistical analysis

All the data were collected in three replicates. One-way analysis of variance (ANOVA) was used to compare the means using Minitab version 16. The linear regression method was used to test the correlation between moisture content before frying and fat content after frying (with and without pre-drying, food gums and different concentration level) using Microsoft Excel Windows 10. The statistical significance was set at $\alpha = 0.05$.

Results and Discussion

Effects of food gums and pre-drying intermediate products on the fat and moisture content of fabricated fried chips

No food gum

As shown Table 2, significantly ($p < 0.05$) lower fat content were observed for 90 min pre-dried chips (15.66 % w/w) compared to the control (19.56 % w/w). The reduction in fat content by 20 % after pre-drying the intermediate products for 90 min could be due to the reduction in moisture content from 25.04 to 8.76 % with increasing pre-drying time. Generating an external crust forming a film barrier could have influenced the amount of oil transferred into the porous crust during frying. The moisture loss with pre-drying is linked to the lower fat content of the final product (Debnath *et al*., 2003; Jia *et al.,* 2018).

On the otherhand, the final moisture contents of the fabricted fried chips with 60 min (3.28%) and 90 min (1.12%) pre-drying were significantly ($p < 0.05$) lower compared to the samples without pre-drying (5.16 % w/w) as shown in (Table 2). The pre-drying treatments (60 and 90 min) have lowered the moisture on the fried chips, resulting in lower moisture content of fabricated fried chips. Pre-drying for 60 min could be more energy-saving and cost-efficient in reducing the fat and moisture contents of fried chips. This could result in better quality, such as crispiness and shelf life.

Gellan gum

The addition of gellan gum (2 % w/w) without pre-drying reported the highest fat content (26.11 % w/w) with 27.24 % intermediate products moisture content. (Table 2). The fat content was reduced to 23.21 % with 60 min and 16.49 % with 90 min pre-drying. This could be due to reduction in moisture content of intermediate products to10.63 and 6.94 % respectively after 60 and 90 min pre-drying. As a result of pre-drying the intermediate products,less oil enters into the products during deep-frying. Previous research showed that mixing gellan gum (2 % w/v) to pasty mix reduced fat content by 31 % after frying (William & Mittal, 1999) and sev by 32 % (Bajaj & Singhal, 2007). However, the effect of pre-drying was not investigated.

The addition of gellan gum (2 % w/w) and 90 min pre-drying had a significant effect ($p < 0.5$) on the moisture content of fabricated fried chips compared to the control (Table 2). Although our work indicated that gellan gum (2 % w/w) has the ability to affect the moisture migration with pre-drying treatment, Bajaj & Singhal (2007) observed higher retention in moisture content (41%) with gellan gum. Thus, the reduction in intermediate products moisture by pre-drying could have decreased the gradient of water –oil transfer.

Guar gum

The fat content of chips with guar gum (2 % w/w) was 20.98 % w/w and further reduced to 15.02 % w/w when pre-dried for 60 min (Table 2). The reduction in intermediate products moisture content from 28.49 % (no pre-drying) to 12.89 % after 60 min pre-drying showed a significant effect in the reduction of fat content from 20.98 to 15.02 %. Previous study showed that, guar gum (0.3 % w/v) reduced fat content by 55 % on potato chips (Garmakhany *et al.,* 2008). Also, Annapure *et al.* (1999) reported 15 % fat reduction with 0.50 % w/w guar gum with fried sev. The reduction in oil uptake with guar gum seems to be dependent on several factors, such as application of the gum concentration and food type.

Fabricated chips with guar gum (except 1 % w/w) and no food gum had no significant effect ($p > 0.05$) on the moisture content without pre-drying (Table 2). The highest moisture content (6.99 % w/w) was observed with gellan gum (1 % w/w) without pre-drying, while the lowest moisture content (1.12 % w/w) was recorded with 90 min pre-drying. Thereby, the water-holding properties of guar gum could have limited the moisture loss during deep-frying (Annapure *et al.,* 1999; Kurek *et al.,* 2017). However, pre-drying samples, even with guar gum, significantly exhibited a reduction in moisture content of fabricated fried chips.

Methylcellulose

Chips with methylcellulose (2 % w/w) without pre-drying had a significantly ($p<0.05$) higher fat content (23.20 % w/w) compared to the control (Table 2). Pre-drying treatments (60 and 90 min) resulted in lower fat contents. Moreno *et al.* (2010) found that methylcellulose (10 % w/w) lowered the oil content by 25 % in potato chips due to the development of a smoother surface. According to Baumann & Escher (1995) and Pinthus *et al.* (1995), surface coarseness facilitates oil absorption and adhesion. Pre-drying can increase solid content and smoothness and could lead to strong resistance to oil absorption during deep-frying (Ziaiifat *et al.,* 2008).

The higher moisture contents of fabricated fried chips with methylcellulose (0.25, and 2 % w/w) without pre-drying were significantly higher ($p < 0.05$) compared to pre-dried samples (Table 2). Significant reduction in moisture content (1.15 % w/w) was recorded with methylcellulose (0.75 % w/w) and pre-drying for 90 min. The changes in the intermediate products surface structure with methylcellulose and pre-drying could have developed a protective film barrier influencing the water loss during frying. Fried food with gums formed fewer voids preventing the steam from escaping the porous crust (Kurek *et al.,* 2017).

Xanthan gum

Incorporating xanthan gum (0.25 % w/w) without pre-drying resulted in 21.94 % w/w fat content after deep frying (Table 2). The fat content was reduced to 14.46 % after 90 min pre-drying. Garmakhany *et al.* (2008), found that xanthan gum reduced oil absorption in fried potato products by 56 % due to a less porous crust development and improved quality, such as texture and colour (Akdeniz *et al.,* 2006). Xanthan gum is commonly used to enhance the product quality at a low cost by the food industries (Habibi & Khosravi-Darani, 2017; Bi *et al.,* 2018).

Fabricated chips with xanthan gum were recorded to have the highest moisture contents when samples were not pre-dried (Table 2). However, pre-drying intermediate products with or without xanthan gum significantly ($p < 0.05$) reduced the moisture content of chips. This result could be due to the thermal stability and high-water binding property of xanthan gum. Despite deep frying of intermediate products at a higher temperature, fabricated fried chips with xanthan gum had no influence on the moisture reduction (Bi *et al.,* 2018). In the case of pre-drying, the quantity of water loss could have modified the surface structure, significantly reducing the moisture content of fried chips (Akdeniz *et al*., 2006).

Table 2. Effects of food gums and pre-drying on fat and moisture contents of fabricated chips

Two facts might have affected the fat content of fabricated fried chips. First, modifying the structure of the intermediate products forming a barrier film resulting in the reduction of oil absorption due to pre-drying. Secondly, the thermal-gelation properties of food gums could contribute to poor porosity where most oil adheres, resulting in the reduction in oil uptake. Overall, the effect of oil uptake during frying is influenced by pre-drying and the addition of food gums.

Change in fat content compared to the control

Pre-drying and food gum treatments have negative and positive changes in the fat content compared to the control (Fig. 1). The highest reduction in fat content (36.55 % w/w) was found in chips with gellan gum (0.75 % w/w) pre-dried for 90 min. The increase in fat content (18.64 % w/w) was recorded in samples with gellan gum (2 % w/w) pre-dried for 60 min. Thus, our work indicated that the effect of pre-dried intermediate products with guar gum and xanthan gum consistently increased fat content reduction.

The change in the fat content compared to the control (no food gum and without pre-drying) could be due to the development of the porous crust affecting oil uptake during deep frying. The type and amount of food gum concentration could have affected the thermo-gelling and formation of the film barrier influencing the oil uptake during frying. In the case of pre-drying, increasing pre-drying from 60 to 90 min causing further reduction of moisture before deep-frying may have reduced the moisture-oil transfer increasing fat reduction during deep-frying.

Figure 1. Percentage change in fat content compared to the control

Correlations between moisture contents of intermediate products and fat contents of fabricted fried chips

As shown in Table 3, a good correlation ($R^2 = 0.74$) was observed between the moisture content of intermediate products and the fat content of fabricated fried chips with xanthan gum. A Other samples with and without food gums demonstrated poor correlations. The relationship between moisture content of intermediate products and fat content of fried products depends on the type of food gums.

The moisture reduction with pre-drying is linked to the fat content of the final product. For instance, 10 % moisture reduction by pre-drying before deep-frying results in 10 % less fat content after deep frying (Debnath *et al.,* 2003). However, in their study, the effect of adding food gums was not examined.

Table 3. Correlation between moisture reduction of intermediate products and fat contents of fried chips

Conclusions and Consideration for Further Research

The fat content of fabricated fried chips is dependent on the type of food gums and pre-drying treatments. Chips with lower fat content can be produced by addition of food gums at 0.25 % w/w and pre-drying for 60 or 90 min. Among the type of food gums used in the study xanthan gum is the most effective in reducing fat content of the final product. Pre-drying for 60 min seems to be an economical way of reducing the moisture and fat contents of fabricated fried chips. The correlation between the moisture content of intermediate products and fat content of fried chips also depends on the type of food gums.

Further work remains to be done to determine the increase in protein and dietary fibre on fried chips with the addition of lupin flour. Sensory evaluation and other quality of parametters (chips thickness, hardness, colour, etc.) should be conducted to determine consumer acceptability of low-fat chips with food gums, lupin flour and pre-drying treatments. Imaging analysis to determine the surface porosity of chips also be recommented.

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Data availability

No data has been used in the preparation of this paper.

Ethical Guidance

Ethics approval was not required for this research.

Conflict of interest

The authors declare no conflict of interest.

Reference

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The article clearly describes how the moisture content of semi-product has influenced the fat content of fried foods. The discussion in reducing food moisture by pre-drying was informative in reducing fat content in fried foods.

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This research study described the sensory effects of increasing dietary fibre and protein with the addition of lupin flour concentration. The article provided major health issues with nutritional deficiencies while comparing with other research which helped with further reading. Overall, the report was easy to read and informative.

Jia, B., Fan, D., Yu, L., Li, J., Duan, Z. & Fan, L. (2018). Oil absorption of potato slices predried by three kinds of methods. *European Journal of Lipid Science and Technology,* **120**, 1-9.

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This article described clearly the effects of pre-drying and food gums on oil uptake of fried foods during deep frying. The introduction was very informative in setting out the topicality of the research in terms of recent publications. The discussion made useful comparisons with other research which helped with further reading. Overall, the article was easy to read and informative.

Mallikarjunana, P., Chinnan, M.S., Balasubramaniam, V. M., Phillip, R. D. (1997). Edible coatings for deep-fat frying of starchy products. *LWT - Food Science and Technology*, **30**, 709-714.

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The article clearly summarised the major parameters and mechanism involved in oil absorption while comparing with different research outcome. The discussion was very useful in reducing fat content in fried foods.

Table 1. Fabricated chips with gellan gum, guar gum, methylcellulose or xanthan gum and concentrations

Ingredients	Control	0.25 % w/w	0.75 % w/w	1 % w/w	2 % w/w
Potato flakes (g)	89.00	88.75	88.25	88.00	87.00
Lupin flour (g)	10.00	10.00	10.00	10.00	10.00
Baking soda (g)	1.00	1.00	1.00	1.00	1.00
Gellan gum, guar gum, methylcellulose or xanthan gum (g)	0	0.25	0.75	1.00	2.00
Total dry ingredients	100.00	100.00	100.00	100.00	100.00
Water (ml)	30.00	30.00	30.00	30.00	30.00

Table 2. Effects of food gums and pre-drying on fat and moisture contents of fabricated chips

Food gums (% w/w)	Pre-drying time (min)	Gellan gum			Guar gum			Methylcellulose			Xanthan gum		
		MC-IP (%)	FC-C (% db)	MC-C (%)	MC-IP (%)	FC-C (% db)	MC-C (%)	MC-IP (%)	FC-C (% db)	MC-C (%)	MC-IP (%)	FC-C (% db)	MC-C (%)
Control	0	25.04±1.45^{c}	19.56 ± 0.95^{c}	5.16 ± 1.57^{ab}	25.04±1.45b	19.56 ± 0.95ab	5.16 ± 1.57^{b}	25.04±1.45^{b}	19.56 ± 0.95^{bc}	5.16 ± 1.57^{a}	25.04±1.45^{b}	19.56 ± 0.95^{abc}	5.16 ± 1.57^{ab}
0	60	8.88±0.83^{gh}	18.02 ± 1.99^{cde}	3.28 ± 0.37^{cd}	10.44±0.76^{d}	18.02 ± 1.99^{bcd}	3.28 ± 0.37^{c}	10.44±0.76^{c}	18.02 ± 1.99^{cd}	3.28 ± 0.37^{bc}	10.44±0.76^{cde}	18.02 ± 1.99^{cde}	3.28 ± 0.37^{bc}
0	90	8.76±1.12^{gh}	15.66 ± 2.37^{ef}	1.12 ± 0.51^{gh}	10.34±1.29^{d}	15.66 ± 2.37^{def}	1.12 ± 0.51^{e}	10.34±1.29^{c}	15.66 ± 2.37^{de}	1.12 ± 0.41^{d}	10.34±1.29^{cdef}	15.66 ± 2.37^{efg}	1.12 ± 0.51^{d}
0.25	0	25.06±0.89^{c}	17.95 ± 1.34^{cde}	5.13 ± 0.52^{ab}	28.89±0.13^{a}	17.06 ± 1.99^{bcde}	4.80 ± 1.05^{b}	26.67±0.54^{ab}	20.26 ± 2.87^{bc}	4.91 ± 1.03^{a}	26.78±0.62^{a}	21.94 ± 0.69^{a}	6.12 ± 0.97^{a}
0.25	60	10.91±0.44^{de}	14.93 ± 2.14^{fg}	2.05 ± 0.74^{defgh}	13.05±0.74^{c}	15.69 ± 1.11^{def}	2.56 ± 1.08^{cd}	11.28±1.07^{c}	15.29 ± 1.24^{e}	2.83 ± 0.29^{bc}	11.79±0.32^{c}	14.88 ± 0.33^{fg}	3.36 ± 0.14^{bc}
0.25	90	9.22±0.14^{fgh}	13.82 ± 2.61^{fg}	1.71 ± 1.20^{efgh}	10.04±0.83^{d}	14.12 ± 0.04^{f}	2.66 ± 0.75^{cd}	11.56±1.14^{c}	15.42 ± 1.19^{e}	2.95 ± 0.51^{bc}	11.00±1.26^{cd}	14.46 ± 1.68^{fg}	2.61 ± 0.65^{cd}
0.75	0	29.02±0.19^{a}	18.61 ± 1.59^{cd}	6.63 ± 1.21^{a}	25.56±0.78^{b}	18.44 ± 1.05^{bc}	5.00 ± 0.08^{b}	26.31±0.93^{ab}	21.97 ± 0.82^{ab}	2.90 ± 0.40^{bc}	26.93±1.04^{a}	19.81 ± 1.09^{abc}	6.00 ± 0.87^{a}
0.75	60	10.10±0.71^{efg}	14.12 ± 1.94^{fg}	1.49 ± 0.50^{fgh}	12.24±0.63^{c}	14.67 ± 2.28^{ef}	3.02 ± 1.00^{c}	10.57±1.97^{c}	18.54 ± 1.07^{c}	1.15 ± 0.83^{d}	10.09±0.86^{def}	14.75 ± 0.09^{fg}	3.39 ± 0.90^{bc}
0.75	90	8.22±1.79^{hi}	12.41 ± 0.65^{g}	2.93 ± 0.30^{def}	10.14±0.24^{d}	13.97 ± 1.41^{f}	2.61 ± 1.15^{cd}	11.67±1.77^{c}	15.62 ± 0.69^{de}	2.62 ± 0.14^{bc}	9.15±1.24^{ef}	13.57 ± 1.25^{g}	2.76 ± 2.13^{cd}
1.00	0	28.52±0.45^{ab}	23.17 ± 0.41^{b}	6.00 ± 0.58^{ab}	27.77±0.73^{a}	18.87 ± 1.10^{ab}	6.99 ± 0.52^{a}	27.89±1.17^{a}	21.77 ± 1.18^{ab}	3.12 ± 0.17^{bc}	26.84±1.04^{a}	20.68 ± 0.28^{ab}	5.77 ± 0.69^{a}
1.00	60	11.88±1.28^{d}	16.41 ± 2.23^{def}	2.42 ± 0.39^{defg}	13.33±0.72^{c}	16.24 ± 0.43^{cdef}	2.53 ± 0.85^{cd}	11.53±1.71^{c}	19.90 ± 1.89^{bc}	3.84 ± 2.34^{ab}	11.93±0.36^{c}	14.84 ± 2.03^{fg}	2.76 ± 1.58^{cd}
1.00	90	8.29±0.43^{hi}	16.23 ± 0.76^{def}	3.15 ± 1.67^{cde}	9.71±0.16^{d}	14.94 ± 1.90^{ef}	2.22 ± 0.61^{cde}	10.31±0.89^{c}	15.79 ± 0.67^{de}	1.98 ± 0.50^{cd}	10.57±0.85^{cde}	14.98 ± 2.95^{fg}	1.89 ± 1.32^{cd}
2.00	0	27.24±0.56^{b}	26.11 ± 0.38^{a}	4.64 ± 1.43^{bc}	28.49±0.98^{a}	20.98 ± 0.35^{a}	5.78 ± 0.68^{ab}	25.50±0.91^{b}	23.20 ± 0.87^{a}	4.77 ± 0.86^{a}	27.12±0.58^{a}	18.69 ± 1.03^{bcd}	7.02 ± 0.25^{a}
2.00	60	10.63±0.88^{def}	23.21 ± 1.46^{b}	1.58 ± 0.27^{fgh}	12.89±2.01^{c}	15.02 ± 1.32^{ef}	1.56 ± 0.82^{de}	10.70±1.45^{c}	20.16 ± 1.32^{bc}	2.12 ± 0.24^{cd}	11.46±0.41^{cd}	16.91 ± 1.43^{def}	2.98 ± 2.02^{cd}
2.00	90	6.94±0.94^{i}	16.49 ± 0.55^{def}	0.77 ± 0.95^{h}	9.75±1.88^{d}	15.37 ± 1.86^{ef}	2.15 ± 0.35^{cde}	11.13±1.16^{c}	18.78 ± 1.60^{c}	2.71 ± 0.10^{bc}	8.81±1.40^{f}	15.00 ± 0.88^{fg}	2.40 ± 1.38^{cd}

Data are presented as means ± standard deviation. Means with different superscripts indicate statistical significance ($p < 0.05$).

MC-IP = Moisture content of intermediate product

MC-C = Moisture content of fabricated fried chips

FC-C = Fat content of fabricated fried chips

Table 3 Correlations between moisture contents of intermediate products and fat contents of fabricated fried chips

Food gum	Regression equation	Coefficient of Determination (R^2)
Gellan gum	y = 0.32x + 12.89	0.41
No food gum	y = 0.21x + 14.56	0.43
Methylcellulose	y = 0.28x + 14.36	0.50
Guar gum	y = 0.23x + 12.42	0.58
Xanthan gum	y = 0.32x + 11.51	0.74

x = Moisture content of intermediate product

y = Fat content of fabricated fried chips

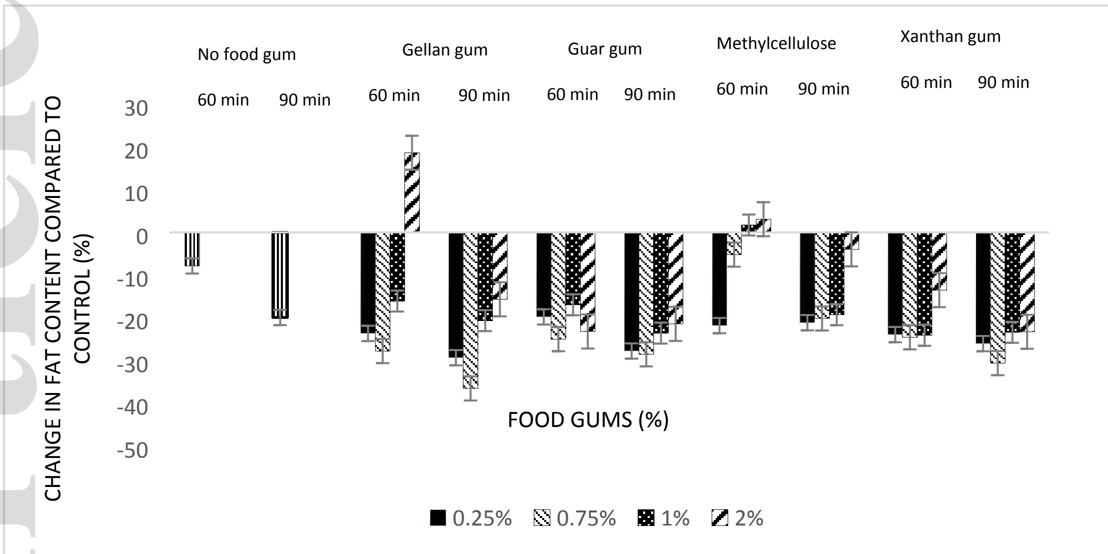

Figure 1. Percentage change in fat content compared to the control