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Impact of isolate soy-protein and shortening on tortilla chips made of local-based Madurese corn

Widya Puspantari[1*], Dayu Dian Perwatasari[1], Kokom Komariyah [1], Budiyanto[1], Imas Solihat[2], Donowati Tjokrokusumo[3]

[1] National Research and Innovation Agency (BRIN), Research Center for Agroindustry, Bogor - Indonesia.
[2] AKA Polytechnic Bogor, Department of Food Nanotechnology, Bogor - Indonesia
[3] National Research and Innovation Agency (BRIN), Research Center for Food Technology and Processing, Yogyakarta - Indonesia

***Corresponding Author:** Widya Puspantari, National Research and Innovation Agency (BRIN), Research Center for Agroindustry, KST Soekarno Cibinong, Jl. Raya Jakarta-Bogor KM 46 Cibinong, 16911, Bogor - Indonesia, e-mail: widy010@brin.go.id

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Abstract

Tortilla chips on the market have a low protein content, namely 7%, and are less crunchy. Utilizing local Madurese corn flour into fortified tortilla chips is an alternative nutritious snack option for children. In this study, protein content in tortillas was increased by fortification using Isolate Soy Protein (ISP) and increasing crispiness using shortening. The study aimed to investigate the effect of shortening at 1.5%, 2.5%, and 3.5% and ISP at 5%, 10%, and 15% on the quality of corn-based tortilla chips. Fortification increased protein contents from 5.38% to 12.73%. Fracturability increased with ISP and decreased with shortening. Shortening significantly made tortilla chips softer and crispier. The treatments showed a significant difference in L values ($p < 0.05$), thus reducing brightness. Pasting viscosity showed that the addition of shortening and ISP decreased peak and breakdown viscosity from 436.50 to 220.00-142.50 cP and from 212 to 7.50-3.00 cP, respectively. Shortening made the starch stable during heating. The calorie content of tortilla chips with the addition of ISP and shortening ranged from 4589.70 to 5053.50 Cal/g. The selection formula was based on consideration of protein content and product acceptance. The hedonic analysis showed that the tortilla chips with 10% ISP and 2.5% shortening were preferred. It has good nutrition with 10.08% protein, 0.65% lysine, 0.46% tryptophan, and 13.08% fat, mainly palmitic acid and elaidic acid.

Keywords: Fortified tortilla chips; Isolate soy protein; Nutrition; Pasting properties; Physical properties; Shortening.

Highlights

- Optimizing the utilization of local Madurese corn flour and isolated soy protein in the production of tortilla chips with a preferred nutritional profile
- Fracturability increased with isolated soy protein and decreased with shortening. Shortening significantly made tortilla chips softer and crispier

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- The fortification of the product resulted in a substantial increase in protein content, soaring from 5.38% to an impressive 12.73%. In addition to protein, the nutritional profile includes 0.65% of lysine, an essential amino acid, and 0.46% of tryptophan, and 13.08% of fat, mainly palmitic acid and elaidic acid

1 Introduction

Tortilla chips have become a favored snack among consumers of all demographics and age groups. It is crafted from nixtamalized corn flour, these chips are formed into flat triangles, fried to perfection, and seasoned with an array of spices. The consumption of tortilla chips in Madura, Indonesia, has witnessed a notable surge over the past decade, attributed to evolving trends, taste preferences, reasonable prices, and the accessibility of raw materials. Local Madurese corn, the Tambin variety, and used as the main ingredient in making tortilla chips, is known for its sweet flavor and longer shelf life compared to hybrid corn.

Tortilla chips have a relatively low protein content derived from corn, typically ranging from 7% to 14%. Furthermore, they are deficient in essential amino acids, especially lysine (Rababah et al., 2012). Consumption of tortilla chips with low protein content causes malnutrition in children because of the low levels of two essential amino acids: lysine and tryptophan. Adding protein to tortilla chips can be one way to increase protein intake and reduce the problem of malnutrition faced by people in developing countries like Indonesia. Indonesia boasts ample protein sources including soybeans, fish, meat, and seaweed. The food industry has evolved significantly, accompanied by diversification and fortification, thereby capturing consumer attention towards elements such as flavor, texture, and overall quality (Puspantari et al., 2024). The fortification and diversification of products utilizing local protein sources can be undertaken to enhance the nutritional value of tortilla chips. The fortification tortilla chips with soybean-based products (tempeh, tofu, and boiled soybean) at 13% increased consumer preference, protein content until 6.86%, and crunchiness (Afifah et al., 2020).

One substance that has the potential to be added to the corn tortilla chips formulation is Soy Protein Isolate (ISP) due to its high protein content (87.7%). Another concern is the content of essential amino acids, namely lysine of 5.33 g/100 g and tryptophan of 1.12 g/100 g. The addition of ISP doesn't affect the taste, a previous study stated that sago rice fortified ISP flour has better profiles in texture, color, and aroma (Puspantari et al., 2020).

Previous studies that have been developed for the fortification of tortilla chips, among others with broad bean flour, chickpea flour, or isolated soy protein, indicated that adding 9% of broad bean flour, chickpea flour, and ISP increased protein content from 6.4 to 10.5% and decreased hardness and crunchiness (Rababah et al., 2012). Previous research has not discussed in detail the fortification of tortilla chips using ISP and the effect of shortening concentration in the fortification on the texture of tortilla chips. Shortening (vegetable fat) was often added in the formulation of biscuits, chips, and tortilla breads to improve texture quality.

Several studies have used shortening for tortilla breads and other products, such as, shortening in tortilla bread reduced stickiness, improved texture for easier processing, and prevented retrogradation (Bejosano & Alviola, 2015). The tortilla breads become firmer with a blend of saturated fat-oil, even after 24 hours of storage (Buitimea-Cantúa et al., 2018). The eggless muffins made with shortening showed better organoleptic attributes in terms of color and texture compared to those made with butterfat (Singh et al., 2017). Previous studies have used shortening in one concentration to produce tortilla chips to improve texture. Kaur and Aggarwal have added 6% of shortening to the total flour to produce a soft dough of maize potato tortilla chips (Kaur & Aggarwal, 2017).

Evaluation of tortilla chips with either a combination of ISP or shortening has never been carried out. In this study, the combination of ISP and shortening at different levels in tortilla chips was evaluated for protein content, physical properties, amino acids, and fatty acids profiles and sensory quality.

2 Materials and methods

2.1 Materials

The corn flour used is the Tambin variety from farmers in Bangkalan, Madura which had undergone a nixtamalization process. Shortening and palm cooking oil, ISP (Little Herbalist, Indonesia), and shortening (Malinda, Indonesia) were purchased from the local market. All chemical reagents were analytical grade (Merck).

2.2 Experimental design

The study examined variations in the levels of ISP and shortening utilized, encompassing three ISP levels (5%, 10%, and 15%) and four shortening levels (0.1%, 2.5%, and 3.5%). These experimental conditions enable a systematic exploration of the effects of ISP and shortening concentrations on the properties of the resulting tortilla chips, thereby facilitating a comprehensive understanding of the formulation parameters' influence on product characteristics such as texture, flavor, and nutritional composition. The control formula was also made which used 0% ISP and 0% shortening. The total treatment in this study was 13 treatments. Parameters measured include protein content, fracturability testing, gelatinization profile of composite flour, color, calorie value, and sensory assessment of color, texture, and taste of corn tortillas. Furthermore, the selection of the best formula is carried out based on consideration of protein content and product acceptance. The selected product was analyzed for its characteristics through a complete proximate test, fatty acid, and amino acid profiles.

2.3 Preparation of corn tortilla chips

The preparation of corn tortilla chips was carried out according to the method of Perwatasari et al. and Puspantari et al. with slight modifications (Perwatasari et al., 2024; Puspantari et al., 2024). The tortilla chips formulation comprises 80% of corn flour, 15% of ISP, 3.5% of shortening, 1% of salt, and 0.5% of baking powder. These ingredients were thoroughly mixed, after which water is gradually incorporated into the dough, constituting approximately 10% of the total weight. The dough was steamed for 30 minutes and processed using a sheeter to produce the tortilla sheets. The sheets were cut into triangular shapes measuring 3 cm with a thickness of 2 mm into tortilla chips, then dried in the oven at 50 °C for 90 minutes and fried using palm oil at 170 °C for 10 seconds.

2.4 Pasting properties

Pasting behavior of several types of composite flour was analyzed using a Rapid Visco Analyzer (4500 Perten Instruments, Australia) using the standard method for general flour.

2.5 Color profiles

A total of 20 pieces of fried tortilla chips were ground for 1 minute using a blender and color profiles (L*, a*, and b*) and were analyzed using a Konica Minolta Chroma Meter (CR-410, Konica Minolta Inc, Japan). The color of each sample was measured in triplicates.

2.6 Calorific value

The calorific value of the product was measured with an IKA C 6000 version cylinder calorimeter 1.0.17 (IKA, Germany). Place up to 0.5 to 1.0 grams of sample into the sample container. The initial system tests used are Working mode Isoperibol 22 °C, Heater temperature: 22.0054 °C, Chiller temperature: 18.31 °C, Chiller temperature limits: 17.0 °C < x < 20.5 °C, Outer flow test: 00:37 mm:ss, Inner flow test: 00:28 mm:ss.

2.7 Fracturability

Corn tortilla chips' fracturability was evaluated using TA-TX Plus Texture Analyzer (Stable Micro Systems, UK). A crisp fracture rig (HDP/CFS) was used as the probe with a diameter of 0.25 cm (P/0.25S). The load cell used was 25 kg with a pre-test speed of 1.0 mm/s; test speed of 1.0 mm/s; post-test speed of 10.0 mm/s; spacing of 3 mm; trigger type auto-5 g; tare mode auto; and data acquisition rate of 500 pps. The sample was placed in the middle and then the probe in a perpendicular direction will press the sample until it breaks. The calculation was done with 12 repetitions.

2.8 Proximate analysis

Proximate analysis (water, ash, protein, fat, and carbohydrate content based on differences) was carried out according to the AOAC 2005 method 2005.08 (Association of Official Analytical Chemists, 2005).

2.9 Fatty acid and amino acid profiles

Analysis of fatty acid profiles were analyzed using Gas Chromatography (GC) according to AOAC 2002 method 996.06 (Association of Official Analytical Chemists, 2002) while amino acid profiles were analyzed using High-Performance Liquid Chromatography (HPLC) (Cuevas-Martínez et al., 2010).

2.10 The hedonic test

The hedonic test was carried out by giving each panelist two tortilla chips to test. Semi-trained panelists of 30 adults' people, men, and women were asked to evaluate the product in 4 parameters: color, aroma, texture, and taste. Consumer acceptability scores on a 5-point hedonic scale (Scale: 1- dislike it extremely; 2- dislike it slightly; 3-neutral; 4-like it slightly; 5-like it extremely).

2.11 Statistical analysis

The data obtained was tested statistically using one-way Analysis of Variance (ANOVA) and Tukey's test ($\alpha = 0.05$) with software Minitab 19.0 to evaluate the treatment level effect on the test results.

3 Result and discussion

3.1 Protein and Calorie Content

Table 1 demonstrated the protein and calorie contents of fortified tortilla chips by ISP with ranged from 5% to 15%. The protein content exhibited an increase from 5.38% to a range of 6.03% to 12.73%, with a notable augmentation observed upon the addition of ISP by 10% ($p < 0.05$). Similar investigations have documented that fortified wheat tortilla chips with 5.6% ISP elevated the protein content to 4.3% (Gonzalez-Agramon & Serna-Saldivar, 1988). Furthermore, the addition of ISP from 3% to 9% in corn tortilla chips increased protein from 6.4% to 10.5% (Rababah et al., 2012).

Shortening is a fat that can increase calories in a product. Shortening is a type of fat utilized in culinary applications, particularly in cooking and baking. It is derived from hydrogenated vegetable oil. A teaspoon of shortening has 4 g of fat and contains 37 calories. The addition of shortening to the tortilla chips formulas increased the calories from 4670 Cal/g to a range of 4589.70-5053.50 Cal/g. Significant differences occurred in the addition of shortening by 3.5% ($p < 0.05$).

Table 1. Protein and calorie content of tortilla chips.

Formulas	Protein (%)	Calorie (Cal/g)
Control	5.38 ± 0.15[c]	4670.00 ± 16.00[bc]
I5S0	6.03 ± 0.73c[c]	4589.70 ± 83.10[c]
I5S1.5	6.15 ± 0.05[c]	4713.01 ± 13.36[bc]
I5S2.5	7.11 ± 0.22[c]	4714.90 ± 25.00[bc]
I5S3.5	6.80 ± 0.11[c]	4763.09 ± 0.65[bc]
I10S0	10.62 ± 0.12[ab]	4657.42 ± 13.22[bc]
I10S1.5	10.78 ± 0.99[ab]	4781.40 ± 38.70[b]
I10S2.5	10.08 ± 1.12[b]	4815.24 ± 3.10[b]
I10S3.5	10.38 ± 0.83[b]	5032.70 ± 112.00[a]
I15S0	12.64 ± 0.33[a]	4815.10 ± 50.70[b]
I15S1.5	12.63 ± 0.08[a]	4751.45 ± 1.99[bc]
I15S2.5	12.59 ± 0.63[a]	5053.50 ± 28.10[a]
I15S3.5	12.73 ± 1.01[a]	5003.88 ± 6.62[a]

I = isolated soy protein S = shortening.
Results are reported as means ± SD of three investigated series of tortilla chips (n = 3), data in the same column marked with a different letter are statistically significant by Tukey's test ($p < 0.05$).

3.2 Color profiles

The addition of ISP and shortening to the tortilla formulas significantly ($p < 0.05$) reduced the L (lightness), b (yellowness), and increased a (redness) in all samples (Table 2). The L value declined from 92.46 to a range of 91.05-62.00, b value declined from 38.67 to the range of 37.70-28.68 while, a value increased from 6.74 to a range of 7.27-9.55. The yellow color of ISP contributes to the reduction in the brightness of the reddish-yellow corn flour so that the amount of ISP added decreases the brightness of the control tortilla. According to (Rababah et al., 2012), increased redness in fortified chips may be attributed to an increase in the reactivity of reducing sugars with amino acids, which can accelerate the Maillard browning reaction. Another study described that the fortification of tortilla chips with soy increased the redness (Romanchik-Cerpovicz et al., 2012; Puspantari et al., 2020). The addition of shortening in biscuits and cookies decreased the lightness (Singh et al., 2002). In addition to the color profiles, another parameter influencing consumers' preference for tortilla chips is crispiness. Fracturability is used as an indicator of crispiness during an instrumental analysis (Kayacier & Singh, 2003).

Table 2. Color profiles and fracturability of tortilla chips.

Formula	L	a	b	Fracturability (g)
control	92.46 ± 0.05[a]	6.74 ± 0.04[f]	38.67 ± 0.12[a]	577.40 ± 48.60[bc]
I5S0	91.05 ± 0.05[b]	7.27 ± 0.07[e]	36.97 ± 0.11[c]	593.30 ± 54.60[b]
I5S1.5	86.91 ± 0.01[d]	9.18 ± 0.03[b]	36.98 ± 0.01[c]	580.60 ± 72.70[bc]
I5S2.5	86.94 ± 0.10[d]	8.57 ± 0.11[c]	36.06 ± 0.14[d]	548.50 ± 50.20[bc]
I5S3.5	87.56 ± 0.02[c]	8.20 ± 0.02[d]	37.70 ± 0.01[b]	373.50 ± 44.20[ef]
I10S0	64.37 ± 0.51[g]	8.34 ± 0.35[cd]	28.87 ± 0.10[i]	691.47 ± 30.04[a]
I10S1.5	63.51 ± 0.01[h]	8.41 ± 0.02[cd]	28.68 ± 0.01[i]	569.30 ± 58.60[b]
I10S2.5	63.89 ± 0.06[h]	8.42 ± 0.01[cd]	29.33 ± 0.01[h]	508.30 ± 51.20[cd]
I10S3.5	62.60 ± 0.01[i]	8.44 ± 0.01[cd]	28.80 ± 0.01[i]	383.10 ± 27.11[ef]
I15S0	62.95 ± 0.01[i]	9.55 ± 0.02[a]	28.81 ± 0.04[i]	614.60 ± 48.40[b]
I15S1.5	65.29 ± 0.01[f]	7.59 ± 0.01[e]	30.87 ± 0.00[g]	510.00 ± 42.60[cd]
I15S2.5	62.14 ± 0.12[e]	9.43 ± 0.10[ab]	33.76 ± 0.12[f]	437.60 ± 52.2[de]
I15S3.5	62.00 ± 0.09[e]	9.31 ± 0.06[ab]	34.07 ± 0.02[e]	353.53 ± 23.10[f]

I = isolated soy protein S = shortening.
Results are reported as means ± SD of three investigated series of tortilla chips (n = 3), data in the same column marked with different letter are statistically significant by Tukey's test ($p < 0.05$).

Results are reported as means ± SD of three investigated series of tortilla chips (n = 3), data in the same column marked with a different letter are statistically significant by Tukey's test ($p < 0.05$).

3.3 Fracturability

The crispiness of tortilla chips can be assessed by analyzing the fracturability value using a texture analyzer. The degree of crispiness was influenced by moisture content and water activity (Vanin et al., 2009). Low fracture of chips is more accepted by consumers. Without shortening, the addition of ISP increased the fracturability. However, this effect can be avoided with the incorporation of shortening at 2.5 and 3.5 which lowers the fracturability value. The fracturability in samples without shortening (S0) ranged at 593.30-691.47 g while with >2.5% shortening ranged at 383.10-353.53 g. These values fluctuated compared to control which was 577.40 g (Table 2).

The protein of ISP forms a complex with corn starch amylose, creating a strong rigid structure that prevents water from escaping and increases product hardness. These results are similar to the level of tortilla hardness obtained from wheat flour with the addition of 5% and 10% of soy flour, which increased with the value of 4.36, 8.56, and 14.54 N for 0, 5, and 10% addition of soy flour, respectively (Montemayor-Mora et al., 2018). Similarly, other studies have reported that the addition of composite flour consisting of red bean flour and soybeans up to 50% increases the hardness of tortilla chips from 305.13-469.47 gft.

Most tortilla formulations typically contain 5-15% shortening, which greatly influences the flavor, dough machinability, and texture of the tortillas (Bejosano & Alviola, 2015). The current study, shortening at 2.5 and 3.5%, was able to lower the fracturability. By this, the combination of ISP and shortening might have a synergistic effect which allows lower level in fracturability at a lower amount of shortening addition. Shortening is added to the tortilla formula to reduce dough stickiness on the sheeter and improve the quality texture of tortilla. It is important to thoroughly mix the shortening into the tortilla dough to ensure homogeneity and prevent the formation of lumps, as they can result in holes in the finished tortillas. Shortening gives a softer and more tender tortilla texture (Mao et al., 2002). A lower fracturability value indicates that the tortillas are easier to break (crunchier), and the value is close to the commercial tortilla (Happy Tos), namely 333.46 g. According to Sing et al. (2017), shortening can prevent product dryness and provide a softer structure.

3.4 Pasting properties

The pasting properties of tortilla dough were assessed through Rapid Visco Analyzer (RVA) analysis to elucidate the interplay of starch, protein, and fat at various concentrations of ISP and shortening in tortilla formulations. The addition of 15% ISP to the tortilla dough reduced the peak viscosity tortilla from 436.50 to a range of 219.50- 152.00 cP and increased the peak viscosity time from 5.47 to 6.85 minutes, whereas the addition of 5 and 10% ISP had no significant differences (Table 3). The presence of charged amino acids in ISP affected the viscosity of starch during heating. The addition of amino acids (Lys, Ser, Ala, Asp) to potato starch and hydrothermal treatment, significantly increased pasting and gelatinization temperatures, as well as decreased swelling power, peak viscosity, and enthalpy, and higher resistant starch content (Hu et al., 2020).

Shortening is a solid fat that can form amylose and fat complexes. The fat component of shortening combines with amylose to create a V-type helix amylose-lipid complex. In this complex, the outer is hydrophilic, and the inside is hydrophobic (Mohamed, 2021). The amylose-lipid complex can protect the starch structure during heating as seen from the decrease in the starch breakdown viscosity, which means that the starch is stable during heating. The breakdown viscosity of control tortilla chips decreased from 212.00 to a range of 7.50-3.00 cP with the addition of 1.5-3.5% shortening. A similar result was observed when debranched corn starch was treated with lauric acid at a high temperature (90 °C), producing starch-lipid complexes with high melting temperature, stability, and resistance to enzyme hydrolysis (Wang et al., 2020). The setback viscosity had no significant differences in the addition of ISP and shortening.

Table 3. Viscosity profiles of tortilla chips.

Formula	Peak Viscosity (cPU)	Peak Time (min)	Breakdown Viscosity (cPU)	Setback Viscosity (cPU)	Final Viscosity (cPU)
control	436.50 ± 19.10[b]	5.47 ± 0,01[b]	212.00 ± 2.83[c]	204.50 ± 4.95[bc]	421.50 ± 6.36[cd]
I5S0	443.50 ± 2.12[b]	4.15 ± 0.07[c]	282.00 ± 9.90[b]	176.00 ± 5.66[e]	338.50 ± 3.54[g]
I5S1.5	906.00 ± 5.66[a]	3.00 ± 0.00[d]	529.00 ± 1.41[a]	141.50 ± 3.54[e]	517.50 ± 4.95[a]
I5S2.5	220.00 ± 14.10[c]	6.70 ± 0.14[a]	6.00 ± 1.41[e]	206.00 ± 7.07[bc]	418.00 ± 2.83[de]
I5S3.5	184.50 ± 6.36[def]	6.87 ± 0.08[a]	3.50 ± 0.71[e]	206.50 ± 4.95[bc]	392.50 ± 6.36[ef]
I10S0	437.50 ± 10.61[b]	4.10 ± 0.14[c]	149.00 ± 8.49[d]	249.00 ± 1.41[a]	535.00 ± 6.36[a]
I10S1.5	142.50 ± 3.54[g]	6.44 ± 0.33[a]	3.00 ± 0.00[e]	172.50 ± 3.54[d]	313.50 ± 4.95[g]
I10S2.5	199.50 ± 6.36[cde]	6.52 ± 0.30[a]	3.50 ± 0.71[e]	245.50 ± 7.78[a]	445.50 ± 7.78[bc]
I10S3.5	206.00 ± 7.07[cde]	6.90 ± 0.14[a]	6.50 ± 0.71[e]	246.00 ± 5.66[a]	449.50 ± 3.54[b]
I15S0	152.00 ± 5.66[fg]	6.35 ± 0.35[a]	3.50 ± 0.51[e]	185.50 ± 6.36[cd]	327.00 ± 8.49[g]
I15S1.5	171.50 ± 2.12[efg]	6.29 ± 0.26[a]	5.00 ± 0.00[e]	211.50 ± 2.83[b]	369.00 ± 11.31[f]
I15S2.5	219.50 ± 6.36[cd]	6.80 ± 0.28[a]	7.50 ± 0.71[e]	210.50 ± 6.36[b]	416.00 ± 8.49[df]
I15S3.5	156.00 ± 8.49[fg]	6.85 ± 0.07[a]	4.50 ± 0.67[e]	173.50 ± 6.36[d]	330.50 ± 6.36[g]

Results are reported as means ± SD of two investigated series of tortilla chips (n = 2), data in the same column marked with different letter are statistically significant by Tukey's test (p<0.05).

3.5 Hedonic testing

The hedonic test was conducted to analyze the effect of incorporating ISP and shortening on the panelists' preferences regarding tortillas, with assessments based on parameters such as color, aroma, texture, and taste. The samples tested were tortillas that had a protein content of more than 10%, namely tortilla samples with the addition of ISP 10% and 15% and addition of shortening from 1.5% to 3.5% (Table 4). Based on the hedonic test results of 30 semi-trained panelists, the addition of ISP and shortening did not significantly differ in color, aroma, texture, or taste characteristics. The increase in the addition of ISP and shortening in the tortilla formula reduced the color score to a range of 3.63 to 3.34 and aroma from 3.50 to 3.25, while the texture and taste scores experienced fluctuating values with a range of 2.81 to 3.88 and 3.19 to 3.66, respectively. Panelists' assessments across all sensory parameters for the tortilla chips indicated a neutral disposition. Consequently, panelists demonstrated a willingness to accept tortilla chips enriched with ISP and shortening based on their sensory evaluations. Among the six tortilla samples containing 10% and 15% ISP, the variant containing 2.5% shortening received a better response from the panelists.

Table 4. Result of hedonic test of effect ISP and shortening on tortilla chips.

Tortilla Chips	Color	Aroma	Texture	Taste
I10S1.5	3.63 ± 0.75[a]	3.50 ± 0.76[a]	3.56 ± 0.84[a]	3.50 ± 0.80[a]
I10S2.5	3.63 ± 0.75[a]	3.47 ± 0.72[a]	3.88 ± 0.79[a]	3.66 ± 0.97[a]
I10S3.5	3.47 ± 0.84[a]	3.38 ± 0.66[a]	2.81 ± 0.97[b]	3.41 ± 0.98[a]
I15S1.5	3.34 ± 0.94[a]	3.25 ± 0.67[a]	3.13 ± 1.24[a]	3.19 ± 0.86[a]
I15S2.5	3.53 ± 0.88[a]	3.38 ± 0.75[a]	3.63 ± 0.98[a]	3.53 ± 1.01[a]
I15S3.5	3.56 ± 0.85[a]	3.25 ± 0.80[a]	3.10 ± 0.82[a]	3.63 ± 0.75[a]

Results are reported as means ± SD of three investigated series of tortilla chips (n = 3), data in the same column marked with a different letter are statistically significant by Tukey's test ($p < 0.05$).

3.6 Selected tortilla chip

The selected sample was chosen based on consideration of the protein content, and sensory acceptance values. In terms of sensory, the preferred tortilla was tortilla derived from the addition of 10% ISP and 2.5% shortening (I10S2.5). As shown in Table 1, it has a higher protein content (10.08%) than control (5.38%). The results of the proximate analysis of the selected products after frying were fat (14.81%), water (0.32%), ash (2.72%), and carbohydrate by difference (66.36%). The protein content was higher than commercial tortilla chips (Happy Tos) (7.14%) and other fortified tortilla chips were made with 8% of soybean flour (12.5%) (Serna-Saldivar, 2015) and 9% of ISP (10.5%) (Rababah et al., 2012). Healthier tortilla chips were due to lower fat content (14.81%) compared to commercial products (25%).

According to the Indonesian National Standards for corn snacks, the maximum thresholds for water and fat content are 1.5% and 22.5%, respectively (Badan Standardisasi Nasional, 1996). However, the selected chip samples met the established standards, with a water content of 0.32% and a fat content of 14.81%. However, the ash content value of 2.72% is higher than the maximum threshold.

3.7 Fatty acids profiles

Fatty acids are macronutrients in food that provide energy for the human body and contribute to the taste and delicacy of food. They have both detrimental and beneficial effects on the body's health. The content of tortilla fatty acids in Table 5 shows that the selected tortilla chips contained 42.46% of total fatty acids. This high value can be sourced from fatty acids contained in raw materials, namely corn, ISP, and shortening; and comes from the tortilla frying stage using palm cooking oil. The fatty acids content is mostly composed of saturated fatty acids, followed by trans fatty acids and a small portion of unsaturated fatty acids. Fatty acids consist of saturated (SFA) and unsaturated fatty acids (UFA). There are two kinds of bonds, a single bond namely, mono-unsaturated fatty acids (MUFA), and double bonds namely, poly-unsaturated fatty acids (PUFA) (Rustan & Drevon, 2005).

Table 5. Fatty acid and amino acids profiles of selected tortilla chips.

Parameter	Results (% w/w)	Parameter	Results (% w/w)
Fat content	13.08	Amino acid	
Butyric acid, C4:0	0.09	Aspartic acid	1.22
Caproic acid, C6:0	0.09	Threonine	0.49
Caprylic acid, C8:0	0.21	Serine	0.64
Capric acid, C10:0	0.08	Glutamate	2.78
Lauric acid, C12:0	0.31	Proline	0.90
Myristic acid, C14:0	0.50	Glycine	0.50
Myristoleic acid, C14:1	0.03	Alanine	0.78
Palmitic acid, C16:0	19.99	Cystine	0.10
Palmitoleic acid, C16:1	0.04	Valine	0.68
Heptadecanoic acid, C17:0	0.03	Methionine	0.09
Stearic acid, C18:0	1.85	L-leucine	0.60
Elaidic acid, C18:1n9t	18.74	Leucine	1.41
Arachidic acid, C20:0	0.17	Tyrosine	0.33
Cis-11-Eicosenoic acid, C20:1	0.04	Phenylalanine	0.69
Linolenic acid, C18:3n3	0.13	Histidine	0.50
Cis-11,14-eicosadienoic acid, C20:2	0.06	Lysine	0.65
Behenic acid, C22:0	0.02	Arginine	1.01
Cis-5,8,11,14,17-Eicosapentaenoic acid, C20:5n3	0.07	Tryptophan	0.46
Total Fatty acid	42.46	Amino Acid Total	13.83

Palmitic acid, a saturated fatty acid with the largest composition in the product, namely 19.99% w/w, followed by stearic acid of 1.85% w/w and myristic acid of 0.50% w/w. Palmitic acid (16:0) is the most common SFA in food, followed by stearic acid (18:0) and myristic acid (14:0). Main sources of SFA are animal products such as meat and dairy products, and some vegetable oils like coconut oil and palm oil (O'Connor & Rudkowska, 2019). Frying the tortillas using palm oil is the cause of the high palmitic acid in the product. Although often considered to have an adverse effect on chronic diseases in adults, palmitic acid is an important component of cell membranes, secretion, and transport of lipids (Aisyah et al., 2019).

The next fatty acid with the second highest composition after palmitic acid is elaidic acid (C18:1n9t) which is 18.74% w/w. The use of shortening in tortilla products causes the elaidic acid content in tortillas to be high. Elaidic acid belongs to the type of trans fatty acids. Trans fatty acids (TFA) are a trans-configuration of unsaturated fatty acids. Dietary TFA can originate either from industrial sources (iTFA) or natural ruminant sources (rTFA). iTFA are by-products of the hydrogenation of vegetable oils, initially with cis configurations. iTFA is solely present in processed foods containing hydrogenated oils such as fried goods, cookies, commercial cakes, crackers, fried potatoes, potato chips, popcorn, margarine, or shortening (O'Connor & Rudkowska, 2019).

3.8 Amino acids profiles

The amino acids valine, leucine, and isoleucine are the most abundant essential amino acids (Varshney & Saini, 2020). Lysine also serves as a precursor for several neurotransmitters and metabolic regulators. Meanwhile, tryptophan functions as a precursor for several neurotransmitters and regulators of metabolic pathways. Lysine deficiency leads to anemia, delayed growth, loss of appetite, and reproductive tissue. Meanwhile, tryptophan deficiency leads to depression, anxiety, and impatience. Corn lacks essential amino acids lysine, and tryptophan, as a building block in protein synthesis. The lysine content in corn was in the range of 0.212-0.235% and tryptophan was in the range of 0.032% to 0.041%.

The ISP demonstrated a notable abundance of essential amino acids, 5.33% of lysine and 1.12% of tryptophan, and this is indicative of its nutritional quality in terms of these vital constituents (Chuck Hernández & Serna-Saldivar, 2019). Table 5 shows that the selected tortilla chip (I10S2.5) contains 0.65% w/w lysine and 0.46% w/w tryptophan. This result was higher than no fortified corn tortilla chips (0.3%) (Mehta et al., 2020) and fortified tortilla chips with 8% soybean flour had a range of 0.3% to 0.52% (Serna & Saldivar, 2015). Fortified tortilla chips with ISP increased the essential amino acids which are useful for children.

4 Conclusion

This study confirmed that the addition of butter and ISP affects protein content, color profiles, fracture properties, viscosity properties, calories, and hedonic tests. Protein content increased to 12.73% from 5.38%. The addition of shortening decreased lightness, fracturability, and peak viscosity, while the addition of ISP increased the fracturability compared to the control. The addition of 3.5% shortening made the chips softer and crisper and reduced peak viscosity and breakdown to 156.00 cP and 3.50 cP, respectively. The calorie content of tortilla chips ranged from 4670 to 5053.50 Cal/g. Color, aroma, and taste preferences were not significantly different, except for texture ($p < 0.05$). Panelists preferred a chip with 2.5% shortening and 10% ISP (I10S2.5). The selected chip, in terms of protein content and sensory acceptance, was healthier than commercial products, had a higher protein content, contained essential amino acids, and had a lower fat content. This characterization can increase product competitiveness and make it easier to accept in the market. For future research, improving the fatty acid content and changing the frying process to baking is necessary.

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