The Effect of Moringa Leaf Flour (*Moringa oleifera*) Addition on Nutritional Value, Physical Characteristics and Organoleptic Properties of Tortilla Chips

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Abstract. Tortilla chips, which are thin and crispy snacks, are generally made from corn flour using ultra-processing technology. This technology often has a negative effect on the nutritional content of a product. One way to increase the nutritional value of ultra-processed products is to add ingredients using alternative flours with high nutritional value. Moringa leaves are plant-based ingredients with potential nutritional value that are currently receiving a lot of attention. The purpose of this study was to determine the effect of moringa leaf flour on the nutritional content and physical and organoleptic properties of tortilla chip products. The experiment was conducted using a Completely Randomized Design with four repetitions for each treatment of adding moringa leaf flour namely: p_0 (without moringa leaf flour), p_1 (3 g), p_2 (6 g), p_3 (9 g), and p_4 (12 g). The study showed that the best nutritional content was obtained in p_4 tortilla chips, which contained 1.61% water, 22.14% fat, 8.18% ash, 2.15% fiber, 23.63% protein, and 59.87% carbohydrate. However, nutritional value is not directly proportional to its physical and organoleptic properties. The p_1 had the best physical quality, with a total color value of 14.29, hardness of 1577.75 gf, crispness value of 0.72 mm, and in terms of aroma, color, taste, and texture, it was the most preferred.

Keywords: Tortilla Chips, Moringa Leaf, Nutritional Value, Physical Characteristics, Organoleptic

1 Introduction

Many parts of Indonesia, including Java, Bali, Sumatra, Flores, Sulawesi, and Kalimantan, are home to moringa plants (*Moringa oleifera*) [1]. Moringa has been extensively cultivated in East Kalimantan. Many people have started using moringa leaves for vegetables, flour, and healthy juices. Based on the study by Dewi [2], Sukmawati et al. [3], adding moringa leaf flour to food items significantly affects their nutritional content. There have been claims that Moringa was found to be a very nutrient-rich plant. According to Paramita [4], moringa leaves are rich in vitamin A, vitamin B1, vitamin B2,

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vitamin B3, vitamin B6, vitamin C, vitamin E, minerals, protein, and antioxidants such as flavonoid polyphenols and ascorbic acid, which are useful for protecting against damage caused by free radicals. Despite its potential to enhance the nutritional properties of food, moringa has a distinctly bitter taste and is pungent, significantly limiting its large-scale application in food products.

Tortilla was originally from Spanish, meaning or “corn". Tortilla is a Mexican snack with a characteristic thin, crispy shape and comes from corn flour [5]. It has a unique taste and texture and is affordable. Tortilla chips have several shape variants such as rectangles and triangles of different sizes, which make them unique. Tortilla chips have a relatively low nutritional content because there are no additional nutrients other than those derived from the basic ingredients. Excessive processing also results in low nutritional content in tortilla products.

This study aimed to determine the effect of moringa leaf flour on the nutritional value (water, fat, protein, and carbohydrate content) as well as the physical and sensory qualities of tortilla chip products.

2 Material & Methods

2.1 Material

Moringa leaf flour was obtained from Kurma Alif Surabaya, corn flour (Healtycorner Surabaya), and wheat flour (Segitiga Biru PT. Indofood Sukses Makmur TBK), cooking oil (Rose Brand PT. Tunas Baru Lampung TBK), water (Le Minerale), and table salt (Jempol PT. Susanti Megah) and garlic powder (Pada Suka Kayakarsa Bogor). The materials and solvents used for sample analysis were petroleum benzene (Merck), H2SO4 (PT. Aneka Kimia Inti), Kjeldahl catalyst tablets (KjTabs™), and distilled water (CV. Megatamas), and 10 % NaOH (PT. Asahimas Chemical) solution, saturated H3BO3 (Smart Lab), indicators (MM: MB) (Merck), 0.02 N HCl (PT. Asahimas Chemical), 95% alcohol (PT. Likuid Pharmalab), K2SO4 (Merck), NaOH (PT. Asahimas Chemical).

2.2 Experimental Design

This study used a non-factorial Completely Randomized Design (CRD) consisting of five treatments and four replications. The treatments included the addition of moringa leaf flour as follows: p_0 0 g (control), p_1 3 g, p_2 6 g, p_3 9 g, and p_4 12 g. The data were analyzed by Analysis of Variance (ANOVA) using SPSS v.26., followed by Duncan’s Multiple Range Test (DMRT) at a 5% significance level. The hedonic sensory properties were analyzed with SigmaPlot version 15 using the Friedman test method, followed by Dunn's test to determine the differences between treatments. The best treatment in this study was determined using the multiple attribute method [6].

2.3 Tortilla Chips Making Procedure

Tortilla chips were produced by preparing the raw materials, which consisted of 100 g corn flour, moringa leaf flour (according to the treatment), 50 g wheat flour, 2 g salt, 3 g garlic powder, and 110 mL water. All ingredients were thoroughly mixed and kneaded until uniform and homogeneous dough was formed. The dough was flattened using a rolling pin to obtain thin sheets with an approximate thickness of 1 cm. The sheets were subsequently cut into triangular shapes using a mold. The shaped dough was dried in an oven at 60°C for 30 min. Finally, the semi-dried tortilla chips were deep-fried in hot oil at 160°C for 1 min, followed by draining to remove excess oil.

2.4 Analysis

Proximate analysis including moisture, ash, fat, protein, fiber and carbohydrate were conducted according to Sudarmadji et al. [7]. Color analysis by Engelen [8] and Trinderup et al. [9] was performed using a colorimeter (CS-10). The tool was calibrated first and then continued by measuring the sample under a color reader until the light could detect the color of the sample. The color notation is stated in Lab, which states the brightness parameters (achromatic color, 0: black to 100: white). The mixed chromatic color red green is indicated by a value (a^+ = 0-100 for red, a^- = 0–(80) for green). The chromatic color of the blue-yellow mixture is indicated by the b value (b^+ = 0 -70 for yellow and b^- = 0-(-70) for blue). The results obtained will be recorded, and the color will be identified using the Commission Internationale d'Eclairage method. The calculation for the color perception value follows this formula:

$$\Delta E^*ab = \sqrt{((\Delta L^*)2+(\Delta a^*)2+(\Delta b^*))2}$$

where:

ΔL* = L* sample - L* standard (difference between light and dark (+ = light, - = dark)); Δa* = a* sample - a* standard (+ = red, - = green);

Δb* = b*sample - b*standard (+ = more yellow, - = blue)); and

ΔE* = Total color difference

A texture analysis analyzer (CT3 Brookfield) was used to measure hardness and crispness using a cylindrical probe 38.1 mm; length, 20 mm). An organoleptic test was conducted using a 9-scale hedonic test to assess the preference for color, texture, aroma, and taste. The evaluation involved 30 untrained panelists, who were students from the Department of Agricultural Product Technology.

3 Results and Discussion

3.1 Chemical Properties

Moringa leaf flour significantly affected proximate content (moisture, fat, ash, fiber, and protein) (Table 1).

Moisture Content. Moringa leaf flour addition had a significant effect on the moisture content of tortilla. The lowest decrease in moisture content was observed in sample p_4 (1.61 %) compared with the control sample p_0 which was 6,08%. As the proportion of moringa leaf flour increased, moisture content exhibited a corresponding decreased. Furthermore, the substantial dietary fiber content inherent in moringa leaf flour enhances water binding. This observation aligns with that of Nurrohman et al. [10], who reported a decrease in moisture content upon incorporation of moringa leaf flour. The reduction in moisture content can be attributed to the higher proportion of corn flour compared to moringa leaf flour. Husna et al. [11] explained that the variations in moisture content can be attributed to the presence of protein molecules within the material, which exhibit a strong capacity for stable water binding. This capacity arises from the presence of numerous hydrophilic amino acid side chains such as those containing hydrocarbon groups that interact with water molecules.

Additional factors contributing to the decrease in moisture content include processing treatments, such as the drying process using the oven method at a temperature of 60 °C for 30 min and frying with medium heat for 4 min. The reduction in moisture levels enhanced textural characteristics and shelf life; excessively high moisture content significantly increased the texture of tortilla chips, and lower moisture content contributed to extended shelf life. According to the Indonesian National Standard SNI 2886-2015, the moisture content in extrudate snack products is a maximum of 4%; thus, the moisture content of tortilla chips in treatments p_2, p_3, and p_4 meets the SNI requirements for extrudate snacks, except for tortilla chip treatments p_0 (control) and p_1, which still do not meet the specified SNI.

Table 1. The Effect of moringa leaf flour addition on proximate composition of tortilla chip

Proximate content (%)	Moringa Leaf Flour Addition (g)				
	0 (p_0)	3 (p_1)	6 (p_2)	9 (p_3)	12 (p_4)
Moisture	6.08±0.06 e	4.45±0.24 d	3.42±0.17 c	2.47±0.35 b	1.61±0.04 a
Fat	12.01±0.16 a	15.05±0.20 b	17.02±0.09 c	19.99±0.21 b	22.14±0.08 e
Ash	3.32±0.16 a	5.23±0.07 b	6.10±0.14 c	7.23±0.09 d	8.18±0.29 e
Fiber	0.77±0.01 a	0.84±0.02 b	1.35±0.02 c	1.52±0.02 d	2.15±0.03 e
Protein	9.51±0.08 a	12.30±0.11 b	17.42±0.15 c	21.48±0.04 d	23.63±0.07 e

Description: Data (mean ±SD) were obtained from the results of four repetitions. Data analysed by ANOVA. Data within the same row followed by different letters indicates significant differences (DMRT, $p<0.05$).

Fat Content. Moringa leaf flour addition resulted in a significant reduction in the fat content of tortilla chips. The maximum fat content of 22.14% was observed in sample p_4 (12 g of moringa leaf flour), whereas the control sample (p_0) exhibited the lowest fat content (12.01%). As the proportion of moringa leaf flour increased, the fat content also increased. This can be explained by the fat content of moringa leaf flour, which is ± 6,4% [3], which demonstrated a positive correlation between the addition of moringa leaf flour and an increase in the fat content of the product. As per SNI 2886-2015, extruded snack products subjected to frying must have a maximum fat content of 38%.

Notably, the fat content observed in tortilla chips across all treatment groups adhered to the established SNI standards.

Ash Content. Moringa leaf flour addition significantly affected the ash content of the product. The ash content determines the inorganic mineral content of tortilla chips with the addition of moringa leaf flour, and has a significant effect on the ash content of the tortilla chips produced. The sample with 12 g of moringa leaf flour (p_4) exhibited the highest ash content (8.18%), whereas the control sample (p_0) demonstrated the lowest ash content (3.32 %). A positive correlation was observed between the addition of moringa leaf flour and increased ash content. This observation aligns with that of Paramata et al. [12], who demonstrated that the addition of moringa leaf flour significantly elevated the ash content compared to the control group.

Crude Fiber Content. The addition of moringa leaf flour significantly affected the tortilla fiber content. Sample p_4 (12 g of moringa leaf flour) had the highest fiber content of 2,15%. The control treatment (p_0) displayed the lowest fiber content (0,77%. The fiber content in tortilla chips increased with the addition of moringa leaf flour. This observation aligns with that of Dewi [2], who demonstrated that the addition of 3% moringa leaf flour to duck crackers had a significant influence on the crude fiber value (containing 0,95% crude fiber content) compared to the control group (0,37% crude fiber content). Moringa leaves have a fairly high crude fiber content as much as 19,2 grams in 100 grams, it can be used as a source of crude fiber, so they can affect the crude fiber content in products enriched with moringa leaf flour.

Protein Content. The addition of moringa leaf flour significantly affected the protein content of tortilla produced. The highest protein content was found in sample p4 with the addition of 12 g of moringa leaf flour (23.63 %), whereas the lowest protein content was found in sample p0 (9.51%). The protein content of tortilla chips increased with the addition of moringa leaf flour.Salman et al. [13], show that the more moringa leaf flour is added, the more protein content observed in wet noodles. Based on Muchsiri et al. [14], the more moringa leaf flour added to fish crackers, the higher the protein content of the crackers. This was due to the high protein content of moringa leaf flour. According to Saputri et al. [15], the protein content of moringa leaf flour is 11.35%.

3.2 Physical Properties

The addition of moringa leaf flour did not significantly affect any of the physical properties observed. Moringa leaf flour addition only significantly affected the color of the tortilla chips, but not crispness (Table 4).

Color. The effect of moringa leaf flour addition on the performance of tortilla chips is shown in Fig.1. and Table 2. ΔE is the total color difference of L*, a*, and b*, analyzed using a colorimeter. The highest ΔE value was obtained from tortillas with the addition

of 12 g of moringa leaf flour (p_4), with a value of 35.81, whereas the lowest ΔE value was obtained with p_0 (0.92) (Table 3). The results of this study showed that the addition of moringa leaf flour improved the color intensity of ΔE. This is due to the presence of chlorophyll in moringa leaf flour, which gives it a green color. The darker the color of the tortilla chip dough, the more moringa leaf flour was added. However, because of the long frying process, the color of the tortilla chips with moringa leaves became darker. This is because chlorophyll degrades when exposed to heat, causing a loss of green color. In addition, the Maillard reaction also takes place, which is a chemical reaction between reducing sugars and amino acids (proteins) when heated, causing the color of the tortillas with moringa leaf flour addition turning brown to dark brown and showing a distinctive bitter taste [16].

Table 2. Effect of Moringa Leaf Flour Addition on Physical Properties of Tortilla Chips

Analysis	Moringa leaf flour addition (g)				
	0 (p_0)	3 (p_1)	6 (p_2)	9 (p_3)	12 (p_4)
Color (ΔE)	0.92±0.51 a	14.29±0.71 b	20.65±1.02 c	34.28±0.45 d	35.81±0.71 e
Hardness (gf)	1312.62±873.16	1577.75±300.04	1879.62±217.06	1995.62±617.74	2385.62±1018.28
Crispiness (mm)	0.62±0.78	0.72±0.62	0.67±0.29	0.82±0.45	0.22±0.25

Description: Data (mean±SD) were obtained from the results of four repetitions. Data analyzed by ANOVA. Data within the same row followed by different letters indicates significant differences (DMRT, $p<0.05$).

Fig. 1. The actual color of tortilla Chips Product with moringa leaf flour addition

Table 3. Effect of moringa leaf flour addition on color characteristics of tortilla chip

Moringa leaf flour addition(g)	L*	a*	*b	Color Code	Color representation
0 (p_0)	76.09	4.24	27.96	#d6b788	
3 (p_1)	62.75	4.01	25.62	#af946b	
6 (p_2)	56.65	3.82	23.74	#9d845f	
9 (p_3)	45.54	4.91	14.27	#7d6854	
12 (p_4)	44.43	4.51	13.05	#796654	

Description: The color representation results are obtained from the average of L*, a*, and b* on the colorimeter which is continued by determining the color representation using the website https://www.colorhexa.com/

Tortilla chips without the addition of moringa leaf flour (p0) provided brighter color intensity compared to the addition of moringa leaf flour. This occurs because the dough is yellow due to the carotenoid content in corn; therefore, during the frying process, the water content decreases and the color of the tortilla chips becomes dark yellow-brown. Carotenoids are more heat stable than chlorophyll; therefore, the color difference between all treatments is visible in the color representation (Table 2). The color difference can be expressed as ΔE, as listed in Table 3. The value was obtained from the formula to determine the difference between each treatment. The ΔE value ranges from 252.40 to 1.70. The highest value was for the color difference between p0 and p1 (p0-p1), which was 252.40, and the lowest value was for the color difference between p3 and p4 (p3-p4), which was 1.70. The difference in color of tortilla chips shows that different treatments with moringa leaf flour produce quite different colors.

Table 4. Effect of moringa leaf flour addition on color differences between two treatments

Sample comparison	ΔE	Information
p_0 - p_1	252.40	The colors are very contradictory
p_0 - p_2	19.90	Colors tend to be similar
p_0 - p_3	33.48	Colors tend to be similar
p_0 - p_4	35.00	Colors tend to be similar
p_1 - p_2	6.39	At first glance, it looks similar
p_1 - p_3	20.63	Colors tend to be similar
p_1 - p_4	22.22	Colors tend to be similar
p_2 - p_3	14.64	Colors tend to be similar
p_2 - p_4	16.25	Colors tend to be similar
p_3 - p_4	1.70	Seen through close observation

Texture. The results of texture analysis are presented in Table 4. The addition of moringa leaf flour had no significant effect on the hardness and crispness of tortilla chips. The highest hardness value was obtained from p4 (2385.62 gf), while the lowest value was obtained from p0 without the addition of moringa leaf flour, namely 1312.62 gf. The highest crispness value was obtained for p0 and the lowest value was obtained for p4. This is because the concentration of moringa leaf flour in this study was relatively low, which did not affect the hardness and crispness of the tortilla chips. Based on Ruchdiansyah et al. [17], the addition of 10% and 20% moringa leaf flour to crackers causes the texture to become harder and decreases crispness, thus decreasing the overall quality of crackers.

3.3 Sensory Properties

The sensory tests conducted in this study were hedonic tests. The assessment conducted by the panelists of the tortilla chip samples was performed subjectively on a 9-scale (extremely like-extremely dislike). The assessments were conducted by 30 untrained panelists. The sensory test parameters observed were aroma, taste, color, and texture.

Moringa leaf flour significantly affected the hedonic sensory properties of aroma, taste, and color but not texture (Table 5).

Table 5. Effect of moringa leaf flour addition on hedonic sensory properties of tortilla chip

Sensory Properties	Moringa leaf flour addition (g)				
	0 (p_0)	3 (p_1)	6 (p_2)	9 (p_3)	12 (p_4)
Aroma	7.0 a	7.0 a	5.0 a	4.0 b	4.0 b
Taste	7.0 a	6.0 a	5.0 ab	4.0 b	3.0 b
Color	8.0 a	6.0 a	5.0 bc	4.0 c	3.0 c
Texture	5.0	4.5	5.0	4.0	4.0

Description: Data (median) were obtained from the results of hedonic tests. Data were analyzed using ANOVA on Rank. Data within the same row followed by different letters indicates significant differences (Dunn's test, $p<0.05$).

The more moringa leaf flour was added, the less desirable it was for tortilla products. This preference is likely due to the lipoxygenase enzyme in moringa leaf flour, which is known to hydrolyze fats and produce an unpleasant aroma [18]. This proves that the addition of moringa leaf flour to tortilla chips affects the panelists' preference for the resulting aroma.

Panelists preferred to decline the taste of tortilla chips with an increase in moringa leaf flour because the addition of moringa leaf flour to tortilla chips causes the taste to be bitter. This bitterness is attributed to the saponin compounds in moringa leaf flour [19], which can be reduced by reducing its use. The frying process may further activate these compounds and increase the bitterness.

The panelists preferred the color of the P_0 sample without the addition of moringa leaf flour because the color generally resembled tortilla chips. In the P_1-P_4 treatment, it has a dark brown color owing to the presence of green pigments, and during the frying process, a browning reaction occurs in the product. This proves that the addition of moringa leaf flour to the tortilla chips product has a significant effect on panelists' preference.

Panelists reported a reduced liking for the overall texture of samples enriched with moringa. This response was primarily due to insufficient crispiness, which is a key attribute of consumer satisfaction with tortilla chips.

4 Conclusion

The addition of moringa leaf flour significantly affected moisture, fat, ash, fiber, protein, color, and sensory attributes (aroma, taste, and color) but had no significant effect on hardness, crispness, or texture. The best results were achieved with 3 g of Moringa

flour, producing tortilla chips with 4.45% moisture, 15.05% fat, 5.23% ash, 0.84% fiber, 12.30% protein, a color value of 14.29, hardness of 1577.75 gf, crispness of 0.72 mm, and sensory scores: aroma (7), taste (6), color (6), and texture (4.5). The addition of moringa leaf flour is best limited to no more than 3 g, as increased levels have been associated with a decline in consumer acceptance.

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