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Utilization of Chia Mucilage As a Coating of Fried Chicken Fillet: Oil Absorbed Reduction and Physicochemical Properties

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Abstract

One of the most common problems with fried food is its high oil content, which is the main factor of overweight and cardiovascular diseases. For that, the aim is to study the impact of adding chia mucilage CM for the coating of fried chicken fillet on absorbed oil, cooking properties, color, texture, and sensory characterization. Results showed that oil absorption was reduced by increasing the chia mucilage level in samples to achieve 82.24% in the CM 2 % sample. Also, by increasing the level of chia mucilage, the moisture content is effectively maintained and the entry of excess oil into the food sample is prevented. The shrinkage was decreased as the level of mucilage increased and exhibited a low level of shrinkage at 14.49% in the CM 2% sample, compared to 13.54% in the control sample (egg coated). The lowest cooking loss was given for CM 2% 19.65%, while the control sample exhibited 18.79%. The result reflects that chia mucilage exhibited antioxidant properties and retarded lipid peroxidation suppression. It is clear that by increasing the level of chia mucilage both TBA and total volatile basic nitrogen were decreased significantly ($p<0.05$). The highest Browning index BI was found in the MC at 2% followed by the control sample at 91.30 and 77.13 respectively. In conclusion, coating chicken fillets with CM improved chewiness and springiness as well as sensory evaluation, which reveals the possibility of using chia mucilage to reduce oil absorption with high-quality chicken fillets.

Keywords: chia mucilage –coating –physicochemical properties-oil absorbed-fried food

1. Introduction

Frying is a common and conventional method of food manufacturing that depends on oil as a heating medium for rapidly preparing and dehydrating food because of its characteristic flavor, crisp texture, golden color, and other characteristics [1].

Foods that are deep-fried or traditionally fried are prepared by frying in hot oil at 150–200 °C. Their high-fat content gives them their unique flavor and texture [2, 3]. However, during the traditional frying process, fried food absorbs a considerable amount of oil; the oil uptake in fried food could reach 50% of its whole weight [4]. Therefore, one of the most common problems with this type of food is its high oil and calorie content, which is linked to the rising rate of cardiovascular diseases and the increasing number of diseases such as diabetes, hypertension, hypercholesterolemia, and obesity is significant [5]. During frying the product surface acts as a main barrier for water loss and oil absorption, which also influences surface tension hence oil absorption in fried food could be decreased with the help of surface coating [6]. The reduction of the amount of oil absorbed in fried food is one of the most recent research strategies. Nowadays, coating is the most widespread method used for that because it is inexpensive and simple to perform. On the other hand, Coating treatment, however, helps to create a surface that is thicker, tougher, and less porous. Decreased surface tension and increased oil-food interaction could result from coating treatment, which would decrease the amount of oil absorbed [6].

The efficacy of coatings in lowering the absorbed oil of fried food relies on their mechanical and barrier attributes of coating, which are related to coating structure, chemical composition, and formula, as well

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as the temperature and time of frying. Furthermore, Coatings can decrease the quantity of oil absorbed by making the surface of fried food smoother [7, 8].

Hydrocolloids, such as proteins and polysaccharides, generally have desirable gel characteristics, and therefore coatings have an impact on the food's surface structure, enhancing its hydrophobicity and decreasing its pores surface and cracks [9]. As a result, hydrocolloid coatings have a significant impact on reducing oil absorption [10].

Polysaccharides that have thermal gelling or thickening properties have relevance in decreasing the content of oil in fried food and improving moisture retention during frying. Fried food's oil absorption can be decreased by using cellulose derivatives such as hydroxymethyl cellulose, methylcellulose, and carboxymethyl cellulose as well as other polysaccharides like gellan, xanthan, basil seed, and guar gums [11].

Mucilage is a complex polysaccharide that can be soluble in water and consists of uronic acid and monosaccharides linked with glycosidic linkages, glycoproteins, and bioactive compounds[12]. Furthermore, they may replace fat without affecting the added food product's sensory attributes [13].

Chia seeds possess desirable functional components since they are a valuable source of lipids, proteins, and fibers. Furthermore, concerning nutritional qualities and technological functionality, the formulation's many advantageous features are highlighted by the full Application of chia seeds and their fractions [14].

Chia mucilage has several applications such as fat/oil replacer in bakery products [15] it has the potential to enhance water binding and emulsification properties in meat products by controlling pH and ionic strength. Additionally, it can serve as a replacement for eggs in the production of vegetarian and specialty foods, catering to individuals with food allergies. Furthermore, it can serve as a substitute for gluten to achieve the desired structural quality in dishes such as pasta and cakes. It can also be utilized as an emulsifier and stabilizer to attain the desired texture and mouthfeel in ice cream. Additionally, it plays a crucial role in stabilizing the product during transportation and storage, particularly in the case of ice cream [16, 17].

The research purpose is to study the effect of adding chia mucilage with different levels at 0.5%, 1%, and 2% to coat fried chicken fillet on its oil absorption reduction, cooking properties, retarding lipid oxidation and physicochemical properties.

2- Material and Methods

Chia seeds are obtained from a local market. All the chemicals were analytical grade. Chicken fillet from the local market.

2.1. Mucilage extraction

The method of extracting the mucilage from Chia seeds is described by Ahmed et al. [18]. Briefly, Chia seeds were blended with water at a ratio of 1 to 10. After two hours of stirring, the mixture was run through two sieves. The mucilage dried in the oven at 50 ºC.

2.2. Chia Mucilage Characterization

2.2.1. Fourier transforms infrared spectroscopy (FTIR) analysis

The FTIR analysis was conducted at a resolution of 4 cm−1 to confirm the functional groups of mucilage, with a spectral range of 400–4000 cm−1. Three replicate analyses were implemented.

2.2.2. Scanning electron microscopy (SEM)

The mucilage samples were gold-coated and micrographs were captured at a magnification of 6000X using a scanning electron microscope (S-4160 Cold Field-Emission SEM, QUANTA, FEG 250, Thermo Fisher Scientific, and USA).

2.2.3. Zeta Potential.

The zeta potential of chia mucilage has been determined using the Zetasizer Nano Zs instrument from Malvern Instrument, Malvern, UK.

2.2.4. Water-Holding (WHC) and Oil-Holding Capacity (OHC)

The determination of the WHC/OHC was performed using the following procedure [19]. 0.1 grams of chia mucilage were mixed with 20 milliliters of Milli-Q water or maize oil for two minutes. The obtained suspensions were centrifuged for 30 minutes at 699 xg. The volume of the liquid above the sediment was then determined. The water-holding capacity was measured as the ratio of grams of water to grams of the sample, while the oil-holding capacity was quantified as the ratio of grams of oil held to grams of the sample.

2.3. Coating procedure and frying process

Chicken fillets were bought from a nearby local market. The samples were cut into 6 × 6 × 1 cm3 pieces. The chicken fillet samples were marinated or dipped in (Chia seed mucilage 0.5%, 1%, 2%) for 1 minute and then rinsed to get rid of any excess chia mucilage. The control sample was dipped in egg and all samples were breaded. Next, the samples were carefully placed into a domestic deep-fat fryer (Teafall) filled with 1 L of frying oil (sunflower and soybean oil) obtained from a local market. The temperature was carefully controlled throughout the frying process. The frying process was carried out at a temperature of 175°C for 2.5 minutes [20].

2.4. Chicken fillets physicochemical analysis

2.4.1. Chemical composition

In a domestic blender, about 200 g of fried chicken fillet samples (0.5%, 1%, 2%, and control) were minced. Moisture, protein, fat, and ash were estimated by the AOAC [21]. Carbohydrates were calculated using the difference.

2.4.2. pH assay

The pH of a mixture was measured by immersing a combined glass-calomel electrode directly in a beaker containing 10 grams of blended sample and 90 ml of distilled water using a pH meter.

2.4.3. Thiobarbituric acid (TBA)

The colorimetric measurement of thiobarbituric acid (TBA) was determined as mg malonaldehyde/Kg, following the method described by Ohkowa [22].

2.4.4. Volatile base nitrogen TVBN

The determination of TVBN was based on the research carried out by Pearson [23].

2.4.5. Shrinkage ratio

The shrinkage ratio was determined using a planimeter to measure the area of the chicken fillet before and after frying allowing for the measurement of shrinkage, or size decrease. Calculating the average area of the raw coated or fried chicken on all surfaces was necessary due to the relatively uniform size and irregular shape of the chicken pieces. Every piece was carefully positioned on a separate side and clearly labeled to ensure consistency. This procedure was repeated for at least six pieces from each concentration. Based on the average surface area, an equation was utilized to determine the shrinkage (%) of coated and/or fried chicken [24].

$$\text{Shrinkage} = \frac{A1 - A2}{A1} \times 100$$

Where A1 is the area of raw coated chicken and A2 is the area of fried chicken.

2.4.6. Cooking loss

The cooking loss of the fried product is determined by weighing the breaded chicken meat before and after frying [25].

2.4.7. The oil absorption

The oil absorbed by each sample was determined using Soxhlet extraction, following the AOAC method [26].

2.4.8. Color measurements

The Hunter Color Measuring System (Labscan XE, Virginia, USA) was used to measure the color of the fried chicken fillet coated with different levels of chia mucilage. The characterization of color depended on lightness (L), redness (a), and yellowness (b). According to [27] The browning index (BI) plays an essential role in processes that include enzymatic or non-enzymatic browning, as it indicates the consistency of the brown color.

$$\text{BI} = \frac{100}{0.17}\left(\frac{a^* + 1.75L^*}{5.647L^* + a^* - 3.012b^*} - 0.31\right)$$

2.4.9. Texture profile analysis

After frying and allowing the breaded fried chicken meat to settle to room temperature, a texture profile analysis was conducted using a Brookfield texture analyzer CT3 [28].

2.4.10. Sensory evaluation

In the National Research Centre's Food Technology Department in Egypt, a sensory evaluation was carried out. Twenty experienced panelists, ranging in age from thirty to fifty, were chosen to take part in the sensory panel examination. The chosen specific chicken fillet features, including color, flavor, Tenderness, Juiciness, Firmness, and overall acceptability, were measured by the panelists. Ten-point method was used for the evaluation as follows: 2 = very bad, 4 = bad, 6 = satisfactory, 8 = good, 10 = excellent [29].

2.5. Statistical analysis

The experiment was done using a completely randomized design (CRD) with three replications. The experimental data were analyzed using statistical methods, specifically one-way ANOVA and Duncan multiple comparisons. The significance level was set at $P \leq 0.05$. The analysis was performed using SPSS 15.0 for the Windows Software Package [30].

3-Results

3.1. Chia Mucilage Characterization

3.1.1 Fourier transforms infrared spectroscopy (FTIR)

Certain plant mucilage was reported to contain hydrocolloids of complex polymeric substances of a carbohydrate nature, including exopolysaccharides and polar glycoproteins with branched structures. [31]. Fiber, protein, and lipids comprise the primary components of mucilage. Figure 1 illustrates the FTIR spectra of chia mucilage. The bands of chia protein are visible in the transmission at 3600 to 3150 cm-1 in the represented spectra. These bands are identified by the broad bands at 3279 cm-1, which represent the (N-H) stretching of the protein content. The existence of amide I groups that characterize protein is indicated by the 1764-1539 cm-1 region for mucilage [32].

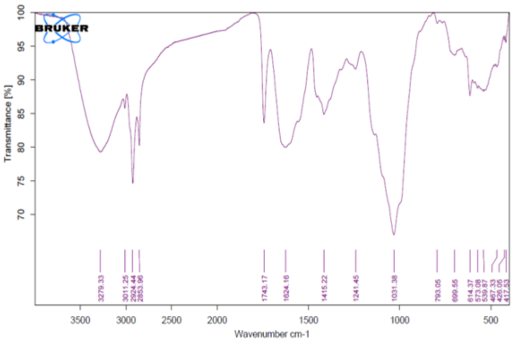

Fig.1.Fourier transform infrared spectrophotometer (FTIR) of chia mucilage

The -C-H elongation of the aromatic rings and the methyl group, which corresponds to fat content, are responsible for the broadband at 2842 and 2908 cm-1 [33]. The greater fiber content of chia mucilage was evident in more than one band group. The carboxyl group (-COO-) of uronic acids is allocated to the bands at 1624 cm-1, which is consistent with the presence of uronic acid in the polysaccharides of chia seed [34]. The mannose ring is the ascribed structure to the transmission bands at 1618 cm-1 for chia mucilage [35]. The band at 1031 cm-1 in mucilage is recognized as the characteristic of polysaccharides and is attributed to the C-O-C of 1→4 glycosidic bond ring vibration and C-OH bending. In addition, the band at 614 cm-1 in the case of chia mucilage, which corresponds to the CH2 with more than 7 carbon atoms, shows the β-anomeric C-H deformation and glycosidic linkages associated with glucopyranose and xylopyranose units [36].

3.1.2. Scanning electron microscopy (SEM).

SEM images of the chia mucilage sample are shown in Figure 2. The extracted mucilage sample exhibited a very hard surface morphology that was flaky, multi-laminated, and more compact (Figure 2). Our findings agree with the observation that chia mucilage has uneven and rough surfaces [37].

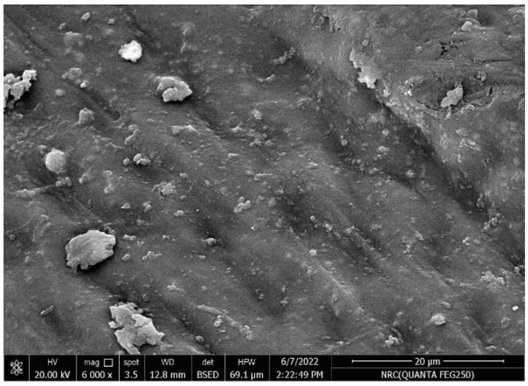

Fig 2. SEM micrograph of chia seed mucilage with magnification (6000 X)

3.1.3. Zeta Potential of chia mucilage

The mucilage sample (Figure 3) exhibited a zeta potential charge with two peaks at negative values (-12.85, -19. mV). The observed negative charge indicated that the mucilage particles exhibited greater stability when dispersed in water.

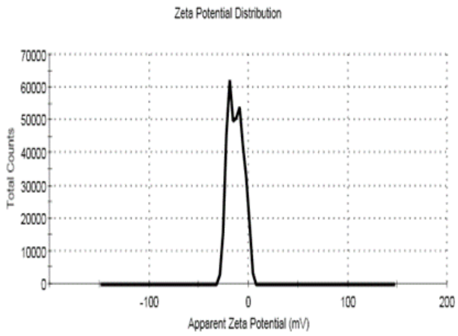

Fig.3. Zeta Potential of chia mucilage

Particles with zeta potential values of ±30mV or higher are typically considered to form a stable dispersion. Furthermore, polysaccharides that are acidic, like mucilage, and have low zeta potentials (30 −30mV), tend to cluster together or form aggregates. Maintaining a stable colloidal or emulsion system at the electrokinetic potential can be quite challenging. This is because a high zeta potential indicates resistance to the consistency or coalescence of emulsion for polysaccharides [38]. The stabilizing and emulsifying properties of CM are a result of steric repulsive forces and are strongly influenced by the protein content [39].

3.1.4. Water Holding and Oil Holding of chia mucilage

The chia mucilage exhibited WHC (38.98 g water/ g sample). The water holding capacity (WHC) was performed to determine the substance's capability of forming gels or highly viscous solutions by binding with or retaining water [40]. The results indicate that chia mucilage has a greater water-holding capacity. This is could be due to this phenomenon may be attributed to the polysaccharides and fibrous structures found in chia mucilage, which enhance its ability to retain or trap water [41]. The chia mucilage exhibited a greater oil holding capacity (OHC) of 5.21 grams of oil per gram of sample. Darwish et al. [37] found chia mucilage OHC at a rate of 5.85 g oil per gram of material. Previous research has indicated that chia mucilage has potential as a stabilizer and emulsifier [42, 43]. These characteristics may be related to the abundant protein and the high content of fiber found in chia mucilage [37].

3.2. Chicken fillets physicochemical analysis

3.2.1. Proximate composition of chicken fillet

The proximate analysis of chicken fillets coated with varying concentrations of chia mucilage is shown in Table 1. The CM 2% sample had the highest moisture content at 52.38%, while the control sample had the lowest moisture percentage at 43.27%. It was observed that the moisture content showed a noticeable increase as the level of chia mucilage increased. It also observed by increasing the level of chia mucilage in coated samples, the oil content was found to be reduced compared to the control samples. There was no significant difference ($p<0.05$) in protein content among all samples, although there were slight significant variations observed in some of the samples.

It was stated that during frying the absorbed oil may be decreased by the coating treatment, which may enhance the interaction between oil and food and decrease surface tension. Coatings' ability to decrease the absorbed oil in fried food is dependent upon their mechanical and barrier properties, which are influenced by the frying temperature, duration, chemical composition, formula, and structure of the coatings. In addition, coatings may cause a reduction in oil absorption by enhancing the uniformity of the surface of fried food [6, 7, and 8].

Table 1: Proximate composition of chicken fillets coated with different concentrations of chia mucilage

sample	Control	CM0.5%	CM1%	CM2%
Moisture	43.27^{a}±2.04	46.37^{a}±2.26	49.84^{b}±1.22	52.38^{b} ± 0.77
Ash	1.38^{a}±0.12	1.55^{b}±0.11	1.70^{bc}±0.05	1.76^{c}±0.05
lipid	13.68^{c}±0.05	13.62^{c}±0.72	11.48^{b}±1.08	5.39^{a}±1.05
Protein	29.90^{a}±0.90	28.82^{a}±1.40	29.06^{a}±0.65	29.84^{a}±0.98
Carbohydrates*	11.77	9.64	7.14	10.63
PH	5.7	5.8	5.8	5.8

Mean values (± S.D.) followed by different letters in the rows are significantly different ($P \leq 0.05$)

Polysaccharides are also reported to be relevant in the reduction of oil content in fried food and increasing the level of moisture retention during the frying process [11]. It was also reported that during the frying process of the quince seed gum-coated fried nugget samples', the moisture content had a significant decrease, while the oil absorption showed a noticeable increase ($p < 0.05$). The differences in fat and moisture levels in fried samples were a result of water being replaced by oil during the evaporation process [44].

3.2.2. Cooking quality and properties of chicken fillets

3.2.2.1. Absorbed oil

The result of oil absorption and the percentage of reduction in absorbed oil of the chicken fillet samples were presented in Table 2. The result indicated that oil absorption was reduced by increasing the chia mucilage level in samples and the highest reduction was achieved by 82.24% in the CM2 % sample. It has been recognized widely that the concentration of coating material has a negative association with oil uptake and moisture loss [45, 46]. Several studies have found that using hydrocolloids such as methylcellulose (MC and hydroxypropyl methylcellulose (HPMC) MC and HPMC in batter effectively decreases the oil absorption in coated fried food, including fish, vegetables, chicken pieces, cheese, and cereal products [47]. It is also observed that CM2 % achieved the highest reduction of absorbed oil at 82.24%. The moisture loss of fried nugget samples was markedly reduced by 30.81% and exhibited the greatest reduction in oil uptake, with a value of 33.21% in the quince seed gum-coated fried samples [44]. As the samples were fried, their lowered moisture loss led to a decrease in oil absorption.

The lipid uptake of the samples was reduced by 34.5% as a result of the moisture loss in deep-fried shrimps being reduced by up to 13.9% when basil gum was used as a hydrocolloid at a concentration of 1% [48]. Furthermore, it had been demonstrated a reduction in oil absorption by approximately 41% when guar gum solution was used at a concentration of 0.9% in deep-fried potato slices [49]. Heat transfer during frying causes moisture to be released and food space to be emptied, which leads to the replacement of oil and increases the amount of oil in fried foods [48, 49].

According to our findings, there is a highly significant correlation between moisture loss and oil absorption. Therefore, increasing the level of chia mucilage maintains moisture content and prevents an excessive amount of oil from entering the food sample. Similar findings have been reported that the presence of quince seed gum in the nugget matrix enhances moisture retention and reduces moisture loss during the process [44]. Furthermore, the elevated vapor pressure of the moisture stored helps to prevent the food tissue from absorbing an excessive amount of oil. Utilizing different types of gum, a significant decrease of 40% in oil absorption and a 10% reduction in moisture loss was observed in chicken nuggets when they underwent deep-frying [50].

Table 2: Cooking quality and properties of chicken fillets

Sample	Absorbed oil%	Reduction of absorbed oil%	Shrinkage%	Cooking loss%
Control	$10.08^{a} \pm 0.45$	------	$13.54^{a} \pm 0.26$	$18.79^{a} \pm 0.26$
CM 0.5 %	$10.02^{a} \pm 0.31$	1%	$19.44^{d} \pm 0.31$	$24.33^{d} \pm 0.32$
CM 1%	$7.88^{b} \pm 0.27$	21.83%	$15.79^{c} \pm 0.09$	$21.26^{c} \pm 0.22$
CM 2%	$1.79^{c} \pm 1.05$	82.24%	$14.49^{b} \pm 0.38$	$19.65^{b} \pm 0.36$

Mean values (± S.D.) followed by different letters in the columns are significantly different ($P \leq 0.05$)

3.2.2.2. Shrinkage ratio

Shrinkage occurs due to the loss of moisture and the subsequent formation and collapse of pore structures. Meat shrinks anisotropically [51, 52]. The rate of shrinkage in biological materials depends upon the orientation of the fiber elongation in either the longitudinal or transverse plane during the frying process. [53, 54].

The control sample exhibited a low level of shrinkage at 13.54%, however, The mucilage-coated sample achieved the lowest shrinkage at 14.49% in the CM 2% sample which indicates that the shrinkage decreased as the level of mucilage increased in the coating. This may be related to the fact that mucilage enhances the ability of meat to retain water, hence lowering cooking losses and enhancing the juiciness of the meat. The degree of shrinkage noticed by a food product is determined by temperature, and if the shrinkage is excessive, it can lead to distortion of forms, hence affecting the final texture and quality characteristics of the product [55].

3.2.2.3. Cooking loss

One of the parameters influencing a product's appearance is Cooking Loss Therefore, a greater Cooking Loss indicates that a less-than-ideal eating quality is expected. The cooking loss (%) of control and mucilage-coated fried chicken fillet is presented in Table 2. The results reveal a significant difference between all samples and the control, with the control exhibiting the lowest cooking loss at 18.79%, followed by CM2% at 19.65%. An additional observation is that an increase in the level of chia mucilage in the coating reduces the cooking loss this may be due to water retaining properties of chia mucilage.

The cooking loss occurs due to the dripping of oil and water as well as the natural evaporation of water. Most chicken fat is derived from chicken skin, while a small quantity of fat adheres to chicken muscle tissue as intermuscular fat. The decrease in cooking loss can be due to either the reduced cooking time or the production of a more distinct crust on the surface of the sample, which physically traps water inside the product's core [56].

During the process of frying meat, a fluid exudation occurs, which causes a decrease in cooking yield and leads to a shrink in meat texture. The fluid primarily consists of water, fat, protein, and other components found in meat. The amount of fluid lost depends on various factors, including the quality of the raw meat (water holding capacity, connective tissue, pH, sarcomere length, fat, and salt content), the type of muscle, and the cooking conditions (time, temperature, and method) [57].

3.2.3 Thiobarbituric acid (TBA) and Volatile base nitrogen (TVBN)

In general, hydroperoxides are highly unstable molecules and do not cause any undesirable sensory qualities until secondary products of lipid oxidation are formed. Hence, the TBARS value is used as an indicator of the byproducts generated by the oxidation of lipids, specifically aldehydes [58]. Furthermore, malondialdehyde, several aldehydes can generate red pigments when they react with TBA. Consequently, the quantity of secondary oxidation products is measured using the TBARS value, which is given as milligrams of malonaldehyde equivalents per kilogram of sample or milligrams of MDA eq/kg.

The TBARS values (Table 3) of chicken fillets varied between 0.46 and 0.75 mg MDA/kg. The TBARS values of all samples lowered as the percentage of chia mucilage increased. All samples had TBARS values below the permissible level of 0.90mg/kg as malonaldehyde, as stated in E.S.S., No.3493/2000 for poultry meat products and its amendments in 16/12/2003 for coated and non-coated poultry meat products.

Data showed that increasing mucilage levels resulted in decreasing TBA values. The result reflects that chia mucilage exhibited antioxidant properties and emphasized lipid peroxidation suppression. That is may be due to the antioxidant activity of chia mucilage which attributed to the significant content of total phenolic compounds in chia mucilage [59]. Based on our findings, it was observed that CM, being a natural antioxidant, has the potential to effectively inhibit chicken fillet oxidation.

Table 3: Thiobarbituric acid (TBA) and Volatile base nitrogen TVBN in chicken fillets

Sample	TBA	TVBN
Control	0.75^{a} ±0.04	0.05^{a} ±0.001
CM 0.5 %	0.70^{a} ±0.04	0.041^{b} ±0.003
CM 1%	0. 55^{b} ±0.01	0.019^{c} ±0.001
CM 2%	0.46^{c} ±0.00	0.018^{c} ±0.00

Mean values (± S.D.) followed by different letters in the columns are significantly different (P ≤0.05

Total volatile basic nitrogen (TVB-N) is a widely considered biomarker for the decomposition of proteins and amines. The TVB-N level of meat, poultry, and fish items rises over time as proteins and other nitrogen-containing components break down during storage. TVB-N buildup coincides with chemical degradation, microbiological spoilage, and significant alterations in sensory acceptability, as well as changes in color and flavor [60].

The data in Table 3 illustrates the TVBN values of chicken fillets, revealing a significant difference (p<0.05) between samples with varying concentrations of chia mucilage. It is obvious that by increasing the level of chia mucilage, the total volatile basic nitrogen was decreased significantly ($p<0.05$). The results show that the lowest TVBN were obtained in the CM 2 % sample and it is observed that there is no significant difference ($P <0.05$) between CM 2% and CM 1% samples. While the control samples exhibited the highest values. The results demonstrate the impressive ability of chia mucilage to prevent the growth of various microorganisms that can lead to protein hydrolysis. This could be attributed to the abundant existence of phenolic and flavonoid compounds, which exhibit strong antimicrobial properties [59].

3.2.4. Color analysis of chicken fillets

Consumers placed great importance on the color of fried meals when making their purchasing decisions [61]. Consumer acceptance is significantly influenced by the color of the chicken after the frying procedure [62]. In Table 4, CM 0.5% shows the highest L* value at 58.49, while CM 2% recorded the highest a* value at 10.95 and the highest b * was in control and CM 2 % at 26.14 and 25.96 respectively. The lowest L* value is found in CM1% at 43.18, a* value at 7.84, and b* value at 17.10.

Table 4: Color parameters of fried chicken fillet

SAMPLES	L*	a*	b*	Δ E	BI
Control	52.48	7.44	26.14	44.14	77.13
CM 0.5 %	58.49	7.94	20.15	40.53	51.42
CM1%	43.18	7.84	17.10	30.84	62.74
CM2%	48.15	10.95	25.96	37.52	91.30

The temperature of the oil and the thickness of the sample during the frying process. The intensity of the color change phenomenon increases as the temperature increases and the thickness of the sample decreases [63]. The meat undergoes discoloration as a result of the oxidation of pigment heme groups [64]. The conversion of myoglobin and hemoglobin to metmyoglobin, which is brown, was attributed to the heat applied to meat by Cross et al [65].

Previous research has indicated that the frying process increases the L* value of fried chicken when the chicken's color is changed to yellow during the initial two minutes. Heat-induced denaturation of myoglobin to Ferro and ferrihemochromes is the primary cause of this alteration, which results in color fading. [66]The L* value of fried chicken further decreases as a result of the Maillard reaction and caramelization that occurs on the chicken's surface after frying for 2 minutes [67]. The highest Browning index BI was found in the MC2% followed by the control sample at 91.30 and 77.13 respectively. The result indicates that adding chia mucilage in the coating of fried chicken fillet by 2% increases caramelization and the Maillard reaction.

During the frying process, the golden surface color is mainly caused by the b* value (yellowness). The increase in the b* value may be attributed to the absorption of oil by meat and the production of chemical browning reactions. Since the BI was considered a reliable indicator of amino acid content, it was employed to identify the color change in chicken that was caused by frying temperatures or techniques [68].

During heat treatment, the color of meat changes as a result of the protein part of myoglobin denaturing [69]. The browning index (BI) is used to measure the intensity of Maillard formation during heat treatment. The samples with the highest values of this indicator were found in MC 2% samples.

Based on the obtained BI index values, it can be concluded that the heat treatment parameters employed during frying resulted in a higher browning index (BI) for the poultry samples. These chemical changes happen when exposed to high temperatures, leading to a direct reaction between reducing sugars and amino acids or peptides. This reaction causes non-enzymatic browning reactions [69].

ΔE represents the overall variation in color between treatments, with a higher ΔE value indicating a more obvious color difference [70].ΔE indicates a noticeable color difference. The Maillard reaction also enhances the color development of various cooking products with the help of amino acids. During frying, the Maillard reaction can lead to the chicken's discoloration. The color intensity is influenced by the presence of reducing sugars, amino acids, or proteins on the chicken's surface, as well as the temperature and duration of frying [71, 72].

3.2.5. Texture properties of chicken fillets

Table 5 shows that the control sample recorded the lowest hardness also the result reveals that increasing the level of addition of CM in the coating decreases the hardness of fried chicken fillet this may be due to the ability of chia mucilage (CM) to retain water is well established. Researchers have found that powdered CM can increase materials' hardness and lower elasticity, while also improving their texture. [73].

The textural characteristics of the products are impacted by the use of mucilage in the coating formulation or frying process. Shear force values take the same pattern of hardness result.CM 0.5% samples the highest hardness and gumminess values ($p<0.05$). It may be that the increased hardness of these samples is a result of the higher moisture loss they had during the frying process.

The lowest hardness recorded by control and CM2% this effect due to the higher the level of mucilage in the samples, the lower the degree of hardness is due to the ability of mucilage to retain moisture in these samples. Texture, particularly the crispy crust, is an essential factor for evaluating fried products after oil absorption. The variations in hardness values resulted in variations in gumminess and chewiness values [74].

It also demonstrates that using CM had a significant effect on texture parameters ($p <0.05$). Coating chicken fillet with CM improved chewiness and springiness. Using CM increased the cohesiveness of the samples. It was additionally reported that incorporating makgeolli fiber into frankfurter samples can enhance the texture of the product [75].

According to reports, incorporating various types of gum can help decrease moisture loss by 10% in chicken nugget samples while they are being deep-fried.

Table 5: Textural properties of fried chicken fillet

Sample	Hardness	Share force	Cohesiveness	Springiness	Gumminess	Chewiness
control	$27.89^{d}\pm1.32$	$11.20^{c}\pm1.36$	$0.12^{c}\pm0.01$	$2.69^{d}\pm0.15$	$3.25^{c}\pm0.57$	$0.01^{c}\pm0.003$
CM0.5%	$37.16^{a}\pm1.99$	$28.36^{a}\pm2.32$	$0.39^{b}\pm0.01$	$4.48^{b}\pm0.12$	$14.45^{a}\pm0.96$	$0.06^{a}\pm0.006$
CM 1%	$33.19^{b}\pm3.06$	$24.04^{b}\pm1.66$	$0.37^{b}\pm0.03$	$4.31^{c}\pm0.02$	$12.20^{b}\pm0.27$	$0.05^{b}\pm0.001$
CM 2%	$30.33^{c}\pm1.82$	$24.74^{b}\pm2.83$	$0.46^{a}\pm0.01$	$4.65^{a}\pm0.03$	$13.97^{a}\pm1.21$	$0.06^{a}\pm0.001$

Mean values (± S.D.) followed by different letters in the columns are significantly different ($P \leq 0.05$)

Additionally, the hardness of the nuggets decreases as the moisture loss decreases [50]. When guar gum is added at a concentration of 0.5%, it enhances moisture retention, reduces oil absorption, and elevates the texture and quality of puri (Indian fried bread) [76]. By incorporating apple pulp into the chicken nugget recipe, the hardness of the nuggets can be decreased and the texture properties can be enhanced, resulting in a higher moisture content [77].

3.2.6. Sensory attributes

In general, the tasters agreed that the samples to which chia was added had excellent sensory properties and were very close in properties to the control sample coated with eggs. The results in Fig.5 showed that, as for all properties, color, flavor, Tenderness, Juiciness, Firmness, and overall acceptability, there was no significant difference ($p < 0.05$) between the egg-coated sample and the chia-coated samples with 2% additive, while a significant difference ($p > 0.05$) was found between the chia samples with different concentrations.

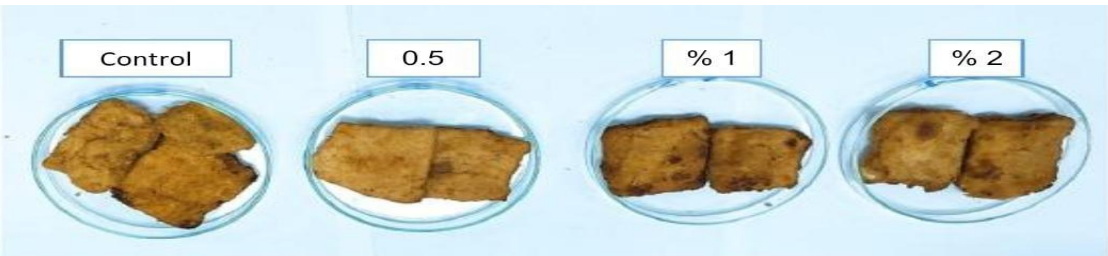

Fig 4: Chicken fillet with different levels of coating with chia mucilage

It was found that in small percentages of added chia, there was a loss of water in the samples, which consequently led to an increase in the hardness of the samples and a decrease in juiciness and Tenderness. As for color, the samples that were covered with 0.5% chia mucilage were light in color and did not give the desired golden color for browned fillets as shown in Fig. 4, while whenever the percentage of chia mucilage increased from 1% and 2%, this led to the samples giving the desired golden color for browning, compared to a sample. Control covered with eggs. These results are consistent with the results obtained from the analysis of texture and color using measuring devices, which indicates confirmation of the validity and realism of the results.

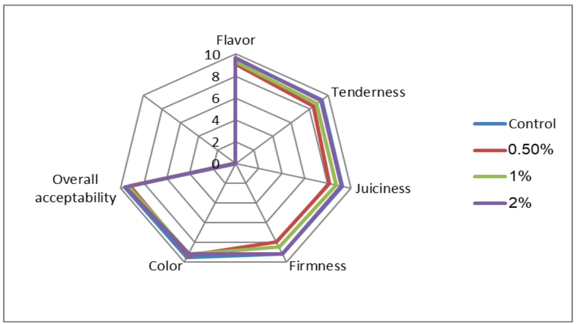

Fig 5: Sensory evaluation of chicken fillets with different levels of coating with chia mucilage

4. Conclusion

The most prevalent approach to reducing oil content is coating treatment, which is characterized by its low cost, straightforward operation, and minimal equipment requirements. This investigation focused on the reduction of absorbed oil, shrinkage, cooking loss, color, texture, and sensory characterization of coatings fried chicken fillets by containing chia mucilage at varying levels of 0.5, 1, and 2% in comparison to the control group. The moisture loss and oil absorption of the chicken fillet sample were reduced by the active coating of chia mucilage at 2% as well as enhancing the sensory properties, texture, and color of fried chicken fillet samples, compared with the control sample (egg-coated fillet). Consequently, the hardness of the fillet texture was reduced after frying. Also, chia mucilage exhibited antioxidant properties and emphasized lipid peroxidation suppression, where increasing the level of chia mucilage the total volatile basic nitrogen was decreased significantly ($p<0.05$).

5. Conflicts of Interest

No conflict of interest is declared by the authors.

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