Journal of Food Science and Technology (Iran)

Homepage: www.fsct.modares.ir

Scientific Research

Investigating the effect of frying method and batter formulation on the physicochemical characteristics of chicken nuggets

Zoleykha Fahimi Vajargahi[1], Mohsen Esmaiili[2*], Arash Ghaitaranpour[2]

1_Master of science student, Department of food industry science and engineering, Urmia University - Iran
2_ Department of Science and Food Industry Engineering, University of Urmia, Iran

ARTICLE INFO

Article History:

Received:2024/9/15

Accepted:2024/12/11

Keywords:

gluten-free batter,
chicken nuggets,
deep fryer,
hot air fryer,
physicochemical properties
.

DOI: **10.22034/FSCT.22.159.316.**

*Corresponding Author E-

m.esmaiili@urmia.ac.ir

ABSTRACT

As one of the most popular fried ready-to-eat foods in the world, chicken nuggets are deep fried. Due to the immersion of the product in this method, the oil content increases, thus causing obesity and related diseases. For this reason, reducing the fat of the product while maintaining the organoleptic properties has been given much attention and research. In this study, chicken nuggets with different batter formulations (wheat flour, rice flour, and quinoa flour) were fried by two methods (deep and hot air) in terms of moisture content, oil content, weight loss, batter absorption rate, and stickiness percentage, color, texture, viscosity, diameter and sensory evaluation were investigated. The oil content, moisture content and percentage of adhesion of the coating to the core were higher in deep frying than in hot air frying. Texture, deep fried chicken nuggets had less firmness and gumminess. The results also showed that the samples coated with quinoa flour had higher moisture content, batter pickup and oil content while they experienced lower cooking loss and coating adhesion to the core. In terms of color, the coating of quinoa dough showed lower L*, b*, and higher a*. The hardness of the nuggets coated with quinoa paste was lower than the other two samples. The results show that hot air frying is generally a healthy method for producing chicken nuggets and a valuable alternative for producing fried protein foods. As a gluten-free grain with high nutritional value, quinoa flour paste can be a good substitute for wheat in reducing the oil content of fried products.

1-Introduction

The shift in lifestyle has led to changes in dietary patterns and an increased reliance on ready-to-eat foods (fast food) due to their quick preparation and availability. Ready-to-eat foods are considered a category of products with unique characteristics and high acceptance. These properties are related to the diverse raw materials and the technology used in the preparation of the food [1-3]. Chicken nuggets are one of the most widely accepted fried ready-to-eat foods globally, prepared through deep-frying, and have become a staple in many diets [4 and 5]. Deep-frying is one of the most popular food processing methods worldwide, altering the sensory and nutritional properties of food due to the complex interactions between the food and the oil. Typically, in deep-frying, foods are immersed in oil/fat, which results in a high-fat content in the final product. Since the consumption of fried foods is unavoidable, reducing fat content while preserving the organoleptic properties of fried foods has become a necessity and a focus of current research in the food industry, especially given the rising rates of obesity and cardiovascular diseases [6-12].

Studies have identified two main methods for reducing the amount of oil in fried foods: modifying the frying process and altering the surface properties of the product [12, 13]. In modifying the frying process, a range of options have been proposed to replace deep-frying with systems that can provide higher nutritional quality. Based on this idea, hot air frying technology has emerged in the market [9]. In this method, oil is sprayed onto the foods' surface, and instead of being immersed in oil, the product is surrounded by hot air [14-18]. In other words, the product comes into contact with less oil compared to deep-frying. As a result, only a negligible amount of oil remains on the surface of the product after frying, making oil absorption during the cooling phase negligible [10, 17]. Investigations into the physicochemical properties and flavor of chicken nuggets during hot air frying and deep-fat frying have shown that hot air frying results in lower fat content compared to deep-frying but requires more time to achieve similar quality characteristics as its counterpart method [19, 20].

Frying impact initiate from the surface of products [21]. Therefore, oil absorption primarily occurs in the crust. For this reason, the characteristics of the food's crust significantly influence oil absorption. The use of batter before frying has gained attention in recent decades due to advantages such as low cost, simplicity, and minimal equipment requirements [12, 13]. Wheat flour is the main component of batter and determines its functional properties. These functional properties depend on the composition and ratio of starch and protein in the flour. Thus, any changes in gluten content or the addition of other proteins can alter the rheology of the batter and, ultimately, the quality of the product [22].

Gluten, due to its unique viscoelastic properties, plays multiple roles in most bakery products. However, consuming gluten-containing foods can cause serious medical complications for individuals with celiac disease. Therefore, recent studies have focused on developing specific batter formulations for coating that are gluten-free while maintaining nutritional and organoleptic properties similar to their gluten-containing counterparts [23-26]. Quinoa, as a gluten-free grain, has been used by researchers as a suitable alternative to wheat due to its high nutritional value (containing essential amino acids and protein quality comparable to milk casein) and its satiety-inducing properties due to its high porosity [27]. The present study aims to increase the variety of gluten-free products by investigating the effects of batter formulation and frying method on the physicochemical properties of chicken nuggets.

2- Materials and Methods

2-1. Preparation of Batter and Chicken Nuggets

The dry ingredients for the batter of each formulation (wheat, rice, quinoa) included flour (98.5% w/w) and salt (1.5% w/w). The dry ingredients were mixed with water (at 25°C) in a 3:5 weight ratio. For the preparation of chicken nuggets, chicken breast was minced using a meat grinder. For every 92% (w/w) of meat, 6% (w/w) onion, 1.5% (w/w) salt, and 0.5% (w/w) seasoning (red pepper, garlic powder, paprika) were added and mixed for two minutes. This mixture was shaped into cubes

[DOI: 10.22034/FSCT.22.159.316]

(1×2×4 cm) and frozen to a temperature below -10°C. The frozen pieces were immersed in the batter for 15 seconds, then left at room temperature (25°C) for 30 seconds to allow excess batter to drain. The pieces were placed on a plastic tray and stored at -10°C until frying [28-30].

2-2. Deep-Frying Process

The deep-frying method used in this study was based on the procedures previously reported by Cao et al. (2020) and Faloye et al. (2021) [19, 31]. For deep-frying, an electric fryer (Princess, NL-5015BH, Tilburg) with a power of 1800 W was used. Approximately 2.5 liters of frying oil were added to the fryer and heated for one hour to reach the desired temperature (180°C). The samples were placed in a basket inside the fryer for six minutes to fry. After frying, the samples were immediately removed from the fryer, and surface oil was absorbed using oil-absorbent paper. The samples were allowed to cool to room temperature before analysis.

2-3. Hot Air Frying Process

For hot air frying, a fryer model (Philips, HD9248, China) with a power of 1300 W was used (Figure 3-2). The fryer was preheated for five minutes at 180°C without adding any samples. The chicken nuggets were then placed in the air fryer chamber and removed after 18 minutes [19].

2-4. Physicochemical Analysis

2-4-1. Measurement of Oil and Moisture Content

Water loss (WL) of the nuggets was determined using the oven-drying method by measuring the weight (grams) of the nuggets before frying (W1) and after frying (W2). The oil content was measured using the Soxhlet extraction method, as described by Nagadi et al. The fat content was determined by measuring the weight (grams) of the nuggets before frying (W_1) and after frying (W_2) based on the AOAC method [28, 32].

1) WL (g $100g^{-1}$ nugget) = $(W_1 – W_2)/W \times 100$

2) OAC (g $100g^{-1}$ nugget) = $(W_2 – W_1)/W \times 100$

2-4-2. Total Weight Loss

The chicken nuggets were weighed before (W_i) and after (W_f) frying using a digital scale (model HS-300S) to calculate the total weight loss.

The total weight loss (LT) was calculated using Equation (3) [33]:

LT=(Wi-Wf)/Wi×100

3-4-2. Batter Absorption Factor

The batter absorption factor (as an indicator of batter adhesion and viscosity) was measured using the difference in weight of the chicken nugget sample (W_n) before and after coating (W_d), calculated using Equation 4 [34, 35].

4) Wet Pickup=(W_d - W_n)/W_n×100

2-4-4. Adhesion percentage of the coating to the product surface

To evaluate the adhesion percentage (C.P), fried chicken nuggets were divided into two parts lengthwise using a knife, and photographs were taken of the cut surface using a camera. The adhesion percentage was calculated using image processing with the ImageJ software based on the formula (5) provided by Albert et al. (2009) [36].

5) C. P =(A/T) × 100

A: The surface of the food item that is covered by the coating, and T: The total surface area of the food item.

2-4-5. Color Evaluation

A colorimeter (CR400 Chroma Meter, Minolta Corporation; Ramsey, NJ, USA) was used to measure the color values in (L*, a*, and b*) system. The value (L*) is an indicator of brightness from black (0) to white (100), the value (a*) represents red (+a*) and green (a*-), and the value (b*) represents yellow (+b*) and blue (b*-). All measurements were performed in triplicate. Additionally, chroma (C*), hue angle (which indicates the dominant color, and the closer this angle is to zero, the redder the sample appears), and overall color change (ΔE) were calculated according to equations 6, 7, and 8 [37].

6) C*=[(a*)2+(b*)2)1/2

7) H*=arctan(b*/a*)

8) $\Delta E = \sqrt{(L^*_{Sample} - L^*_{Control})^2 + (b^*_{Sample} - b^*_{Control})^2 + (a^*_{Sample} - a^*_{Control})^2}$

2-4-6. Texture Evaluation

A texture analyzer (model TAXTPLUS) was used to measure the hardness and fracture distance of chicken nugget pieces, including the crust. The maximum force value was considered as the hardness index. The slope of the curve was used as the strength index, and the distance from the initial point to the point of maximum force was used as the displacement (fracture distance) indicator [38].

2-4-7. Volume Change

Changes in the dimensions of the chicken nuggets before (V_0) and after frying (V_t) were measured using imaging and image analysis with ImageJ software. Volume changes were calculated using Equation 9 [39, 40]:

9] ΔV (%)= $(V_0-V_t)/V_0 \times 100$

[DOI: 10.22034/FSCT.22.159.316]

5-2. Statistical Analysis

All tests were performed in triplicate or more and presented as averages. The obtained data were analyzed using a factorial design. Significant differences between groups were determined statistically using one-way analysis of variance (ANOVA) and the paired sample T-test, along with Duncan's multiple range test, using SPSS 27. Statistical significance was considered at the level of (P<0.05).

3- Results and Discussion

1-3. Physicochemical Analysis

3-1-1. Measurement of Oil and Moisture Content

The frying method and different batter formulations had a significant effect (P<0.05) on the moisture content of the chicken nuggets (Figure 1). The highest moisture content was observed in the chicken nuggets coated with quinoa flour-based batter. This can be attributed to the thicker coating of the nuggets with quinoa flour, which helps retain the moisture in the chicken nuggets. A similar result was obtained by Chayawat and Rumpagaporn (2020) for chicken nuggets coated with rice bran [37]. Additionally, El-Sohaimy et al. (2022) found that quinoa's high water absorption capacity prevents moisture loss, thereby preserving the moisture content [30]. Deep-fried nuggets also had higher moisture content. A similar result was observed by Ghaitaranpour et al. (2018) in deep frying donuts [40].

However, the results of some researchers differed from the present findings. For instance, Cao et al. (2020) reported a higher moisture content in hot air fried chicken nuggets. They attributed this to the lower heat transfer rate in air frying [19]. Santos et al. (2017) and Teruel et al. (2015) also obtained similar results in a study on fried potatoes [42, 43]. The difference in results compared to the present study can be attributed, according to the study by Castro-López et al. (2023), to the longer frying time in the hot air frying process. They demonstrated greater moisture loss after 12 minutes in chicken nuggets and stated that after 12 minutes, the moisture content decreases more significantly [20]. Since the frying time in the hot air method in the present study was 18 minutes, the reduction in moisture content can therefore be linked to this factor.

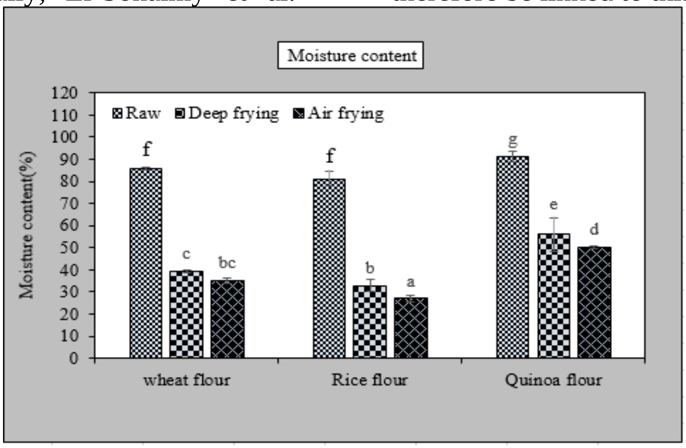

Figure 1: The effect of frying method (deep and hot air) and formulation batter (wheat,Rice,quinoa) on Moisture content (%) of the chicken nuggets, Different letters indicate significant difference (p< 0.05).

3-1-2. Oil Content

Figure 2 shows that batter formulation and frying method have a significant effect (P<0.05) on oil content as well. The oil content in the hot air-fried chicken nuggets was significantly lower than that in the deep-fried ones.

[DOI: 10.22034/FSCT.22.159.316]

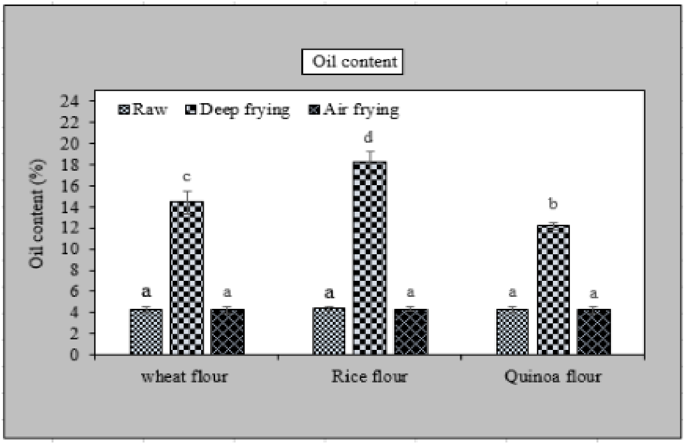

Figure 2: The effect of frying method (deep and hot air) and formulation batter (wheat, Rice, quinoa) on Oil content (%) of the chicken nuggets, Different letters indicate significant difference (p< 0.05).

The reason for this is the reduced contact of the chicken nuggets with oil during hot air frying, which prevents significant oil accumulation on the nugget surface, thereby reducing its absorption during the cooling phase [17]. This result is consistent with the findings of previous studies [17, 19, 43, and 45]. The nuggets coated with quinoa flour also had significantly lower oil content (12.1%). This can be attributed to the high moisture content of the quinoa-coated samples, as the moisture level of the food is an important factor in oil absorption during frying. Generally, higher oil absorption is observed in samples with lower moisture content after frying process. These results confirm the relationship between moisture removal and oil absorption. Similar findings were obtained by several researchers, including Chayawat and Rumpagaporn (2020) and Pinkaew and Naivikul (2019) [34, 37].

3-1-3. Weight Loss

Figure 3 shows the effect of frying method and batter formulations on weight loss. The quinoa-coated samples had significantly (P<0.05) less weight loss. This phenomenon can be attributed to the thicker coating and the high water absorption capacity of the quinoa-coated nuggets, which results in less heat penetration during frying and, therefore, prevents moisture loss and ultimately reduces weight loss [30].

The hot air frying method also had a significant effect on the weight loss of the chicken nuggets, which contrasts with the results of Castro-López et al. (2023) on chicken nuggets fried using both hot air and deep frying methods [20]. As stated in the moisture content section, this discrepancy can be attributed to the longer frying time in the hot air technique, as moisture loss increases after 12 minutes of frying. Since the frying time in the hot air method in the present study was 18 minutes, this can explain the greater reduction in moisture content and, consequently, the increased weight loss.

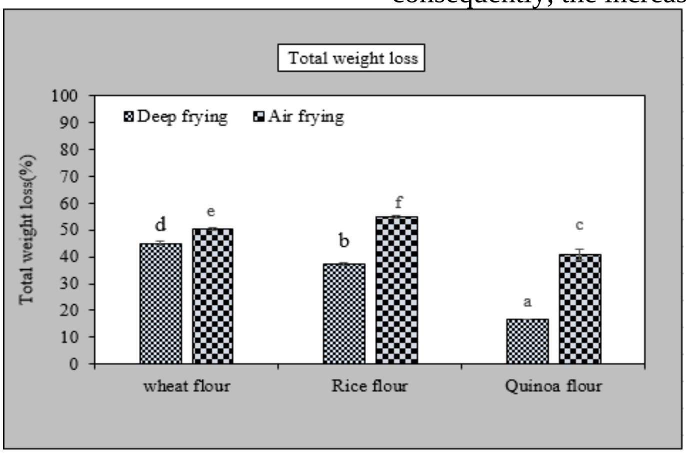

Figure 3: The effect of frying method (deep and hot air) and formulation batter (wheat,Rice,quinoa) on Total weight loss (%) of the chicken nuggets, Different letters indicate significant difference (p< 0.05).

3-1-4. Batter Absorption

Different batter formulations had a significant effect (P<0.05) on the coating absorption index on the surface of the chicken nuggets (Figure 4). The quinoa flour batter had the highest absorption in the chicken nugget coating. This

[DOI: 10.22034/FSCT.22.159.316]

can be attributed, in line with the study by El-Sohaimy et al. (2022), to quinoa's high water absorption capacity, which increases the viscosity of the batter and, as a result, enhances batter absorption [30].

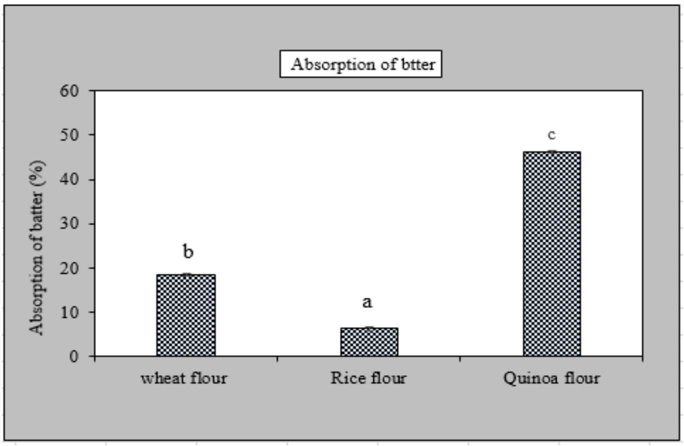

Figure 4: The effect of frying method (deep and hot air) and formulation batter (wheat,Rice,quinoa) on Absorption of batter (%) of the chicken nuggets, Different letters indicate significant difference ($p< 0.05$).

3-1-5. Adhesion Percentage of the Coating to the Product Surface

The adhesion of the coating to the product surface is one of the key factors in evaluating the final quality of nuggets. Figure 5 shows the results of evaluating the effect of different batter formulations and frying conditions on the adhesion percentage of the coating to the product surface, which was obtained using image processing and equation 5. Both variables had a significant effect ($P<0.05$) on the adhesion percentage of the coating to the product surface.

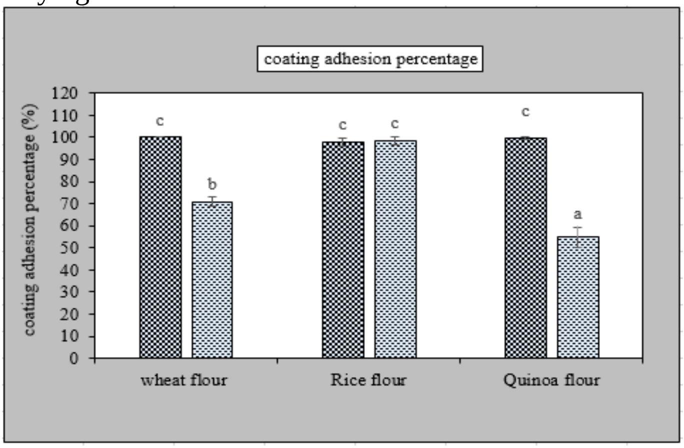

Figure 5: The effect of frying method (deep and hot air) and formulation batter (wheat, Rice, quinoa) on coating adhesion percentage(%) of the chicken nuggets, Different letters indicate significant difference ($p< 0.05$).

In general, the hot air frying method and the use of quinoa flour in the batter significantly reduced the adhesion of the coating to the core (Figure 6). This can be attributed to the thickness of the coating with quinoa flour and moisture retention in the samples. According to the study by Ghaitaranpour et al. (2024), which examined the effect of coating formulation on the structural changes of turkey nuggets during frying [40], it can be explained that the batter forms a layer that prevents moisture from escaping during frying. This phenomenon leads to an increase in vapor pressure beneath the coating layer, causing the coating to detach from the food surface, and consequently reducing the coating adhesion.

[DOI: 10.22034/FSCT.22.159.316]

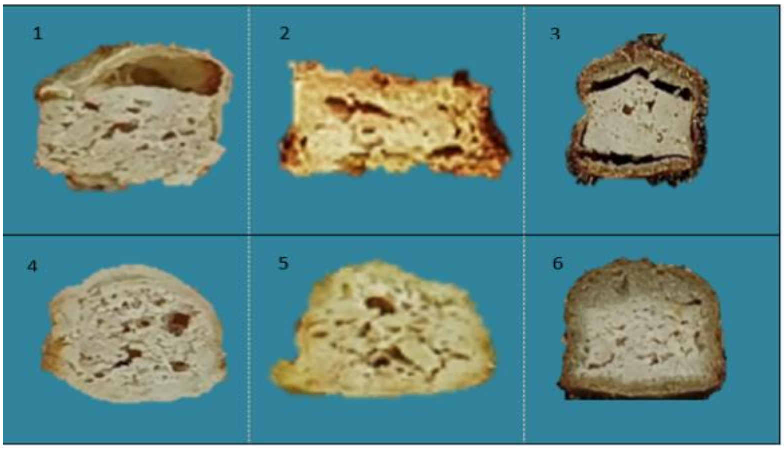

Figure 6: The effect of frying method (hot air and deep) and formulation batter (wheat flour, rice flour, quinoa (%). 1(hot air frying wheat), 2(hot air frying rice), 3(hot air frying flour) on coating adhesion percentage quinoa), 4(deep frying wheat), 5(deep frying rice), 6(deep frying quinoa).

3-1-6. Color

The color of fried products is an important factor that plays a key role in determining the final quality of cooked products, in addition to consumer acceptability [45]. Various changes such as moisture loss, oil migration, frying temperature, frying time, and the Maillard reaction affect the color of the product and influence the appearance of the food [20]. Color measurements were obtained using the (L*, a*, and b*) system. The L* value, which ranges from 0 (black) to 100 (white), is primarily associated with non-enzymatic browning reactions [46], and lower L* values indicate darker products, which are essentially linked to browning reactions. The b* parameter, ranging from -b* to +b*, represents a color change from blue to yellow. a* is another color channel in the a* b* L* color space. The values +a* and -a* represent red and green, respectively. This parameter is directly affected by the browning reactions [48-46].

In the present study, batter formulation and frying method had a significant effect ($P<0.05$) on color parameters (Table 1). The quinoa flour batter-coated nuggets showed lower L*, b*, and Hue angle, and higher a*, and ΔE values. This can be attributed to the high protein content of quinoa, as the high protein content increases the reaction between reducing sugars and amino acids, leading to a darker product [47, 49].

Regarding the frying method, the hot air frying, with an 18-minute frying time, showed higher L*, a*, Hue angle, and ΔE values, and lower b* and C* index values compared to deep frying with a 6-minute frying time. This is explained by the study by Castro-López et al. (2023), which linked the longer frying time of chicken nuggets fried by hot air to this outcome [20], as non-enzymatic browning during air frying occurs much more slowly than in deep frying. Other researchers also reported similar results [19].

Table 1: The effect of frying method (deep and hot air) and formulation batter (wheat,Rice,quinoa) on color parameters of the chicken nuggets. The results were expressed as mean ± standard deviation. Different letters indicate significant difference ($P< 0.05$).

Frying method	Type of batter	L*	a*	b*	H*	C*	ΔE
Deep	wheat flour	57.61 ± 3.4^{b}	1.13 ± 1.9^{a}	30.62 ± 0.8^{d}	87.87 ± 3.6^{c}	30.68 ± 0.7^{c}	28.11 ± 3.1^{b}
	Rice flour	62.74 ± 2.08^{b}	3.24 ± 0.7^{abb}	30.62 ± 0.7^{d}	83.96 ± 1.2^{bc}	30.74 ± 0.8^{c}	21.47 ± 0.7^{ab}
	Quinoa flour	35.04 ± 1.5^{a}	10.27 ± 0.4^{c}	25.34 ± 0.8^{bc}	67.08 ± 1^{a}	27.34 ± 1^{b}	65.93 ± 0.4^{c}
hot air	wheat flour	63.52 ± 7.8^{b}	1.25 ± 0.3^{a}	30.49 ± 2.9^{d}	92.67 ± 9.6^{c}	20.53 ± 2.9^{a}	21.03 ± 9.5^{ab}
	Rice flour	55.14 ± 7.6^{b}	7.07 ± 4.6^{bc}	27.87 ± 1.5^{cd}	76.21 ± 8.6^{ab}	28.97 ± 2.4^{bc}	18.96 ± 1.4^{a}

[DOI: 10.22034/FSCT.22.159.316]

Quinoa flour	38.53±3.4[a]	10.42±2.6[c]	24.22±.6[a]	68.81±6.6[a]	26.44±1.2[b]	64.71±3.7[c]

3-1-7. Texture

Water evaporation, protein denaturation, starch gelatinization, and other reactions are factors that influence the texture changes of products during the frying process [19]. According to Table 2, the frying method and batter formulation had a significant effect (P<0.05) on the hardness and gumminess of the chicken nugget texture. The deep-fat fried chicken nuggets coated with quinoa flour-based batter showed less hardness (0.30±0.1), which can be attributed to both the frying time and the moisture content of the chicken nuggets during the frying process [20, 43]. Furthermore, according to a study by Chayawat & Rumpagaporn (2020) on rice bran-coated chicken nuggets, it can be stated that products with thicker coatings have a softer texture due to moisture retention [37].

Figure 7: The effect of frying method (deep fat-frying and air frying) and formulation batter (wheat,Rice,quinoa) on Textural attributes of the chicken nuggets. The results were expressed as mean ± standard deviation. Different letters indicate significant difference (P< 0.05).

Frying method	Type of batter	Hardness	cohesiveness	Gumminess
Deep fat frying	wheat flour	1.17±0.3[cd]	0.75±0.08[b]	0.88±0.3[bc]
	Rice flour	0.65±0.2[abc]	0.80±0.07[b]	0.52±0.2[ab]
	Quinoa flour	0.30±0.1[a]	0.84±0.03[b]	0.25±0.3[a]
Hot air frying	Wheat flour	1±0.3[bcd]	0.54±0.1[a]	0.55±0.2[ab]
	Rice flour	1.45±0.5[d]	0.80±0.04[b]	1.19±0.5[d]
	Quinoa flour	0.51±0.4[ab]	0.86±0.02[b]	0.44±0.2[ab]

3-1-8. Volume Changes

The frying method and different batter formulations have a significant effect (p<0.05) on nugget volume changes (Figure 7). The deep-fat fried chicken nuggets coated with quinoa flour-based batter showed the least volume change (4.5%). This can be attributed to the moisture content of the chicken nuggets fried by the deep-frying method and the quinoa flour coating. Ghaitaranpour et al. (2024) also mentioned in their study on the effect of coating on turkey nuggets that during the frying process, the size of the food decreases due to moisture evaporation, which leads to structural disruption and, consequently, changes in the dimensions of the food [40].

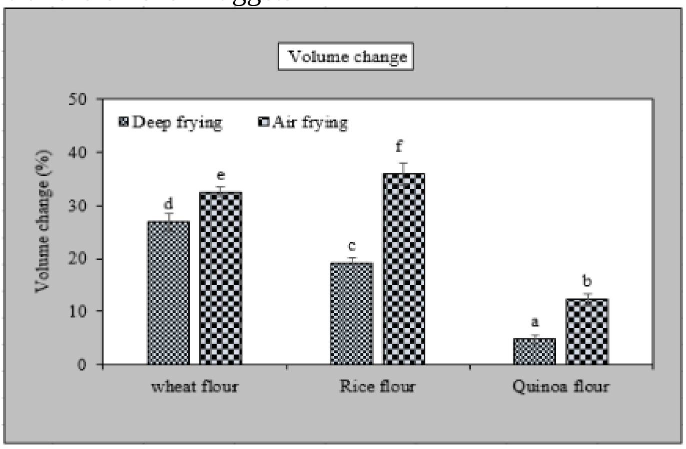

Figure 7: The effect of frying method (deep and hot air) and formulation batter (wheat,Rice,quinoa) on volume change (%) of the chicken nuggets, Different letters indicate significant difference (p< 0.05).

9-1-3. Sensory Evaluation

The sensory characteristics of a food product, such as color, appearance, taste, and texture, influence the consumer acceptance of the fried product. Therefore, sensory evaluation of the samples is very necessary. In the present study, the effect of the frying method and batter formulation on the sensory evaluation (color, appearance, taste, texture, and overall acceptance) of chicken nuggets was investigated. As observed in Figure 8, the frying method and different batter formulations

[DOI: 10.22034/FSCT.22.159.316]

had a significant effect (P<0.05) on the sensory characteristics of fried nuggets.

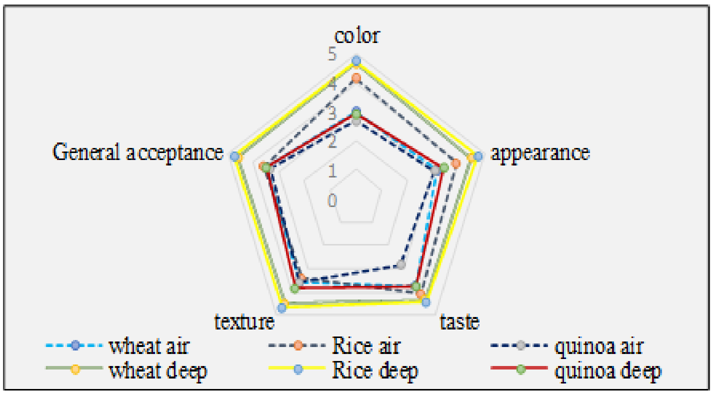

Figure 8:Effect of frying method (deep fat-frying and air frying) and different batter (wheat,Rice,quinoa) on chicken nuggets sensorial characteristics. Different letters indicate significant difference (p< 0.05).

Deep fat fried chicken nuggets showed greater consumer acceptance. In other words, the oil content has effective influence on acceptability of samples. Oil contributes to a shiny color, a pleasant taste, a desirable texture, and, in general, positive acceptance by the consumer. These changes in the properties of the products, including chicken nuggets, can be attributed to the physical and chemical changes that occur during the deep frying process. Similar results have been reported by other researchers [20, 33, 43]. A significant effect (P<0.05) of the formulation on the color, appearance, and taste of the coated samples was observed. The chicken nuggets coated with quinoa flour based batter had the lowest acceptance, which could also be due to the darkening of the product coated with the batter. Similar results have been reported by other researchers [50, 51].

4- Conclusion

The results of the present study showed that although chicken nuggets fried by the hot air method contained less oil compared to the deep-fried ones, they required more time to achieve similar quality characteristics as deep frying. Additionally, this study showed that the use of a gluten-free batter formulation (quinoa), in addition to being gluten-free, significantly reduced the oil content. This was due to the thick crust formed on the chicken nuggets by quinoa flour and the high water absorption of quinoa, which helped retain moisture and prevent oil absorption. Regarding sensory evaluation, the lowest overall acceptance among the batter formulations was observed in the quinoa-coated nuggets, which could be linked to the lower usage of quinoa-containing products by consumers. However, with more education and increased consumption of gluten-free products, including quinoa, consumers' taste preferences could shift towards this food-staffs. In terms of the frying method, hot air frying showed lower acceptance, but considering its effect on oil absorption, it could be a healthier method for producing chicken nuggets and a valuable alternative for producing fried protein foods.

5- Acknowledgments

At the end of this project, the Faculty of Agriculture at Urmia University is thanked and appreciated for their support and cooperation in conducting this project.

6- References

[1] Zasimova, L., 2022. The association between fast-food consumption and job-related factors among Russian adults. Economics & Human Biology, p.101147.

[2] Nemati, A., Matin, S., Sadegh-Hoseini, M., Alipanah-Moghadam, R. and Mohajeri, M., 2020. Is there any difference in fast food consumption between children with different obesity status in Ardabil-Iran? Obesity Medicine, 20, p.100293.

[3] Oniszczuk, T., Kasprzak-Drozd, K., Olech, M., Wójtowicz, A., Nowak, R., Rusinek, R., Szponar, J., Combrzyński, M. and Oniszczuk, A., 2021. The Impact of Formulation on the content of phenolic compounds in snacks enriched with Dracocephalum moldavica L. seeds: introduction to receiving a new functional food product. Molecules, 26(5), p.1245.

[4] Ozen, E. and Singh, R.K., 2020. Heat transfer in breaded and non-breaded chicken nuggets baked in a pilot-scale radiant wall oven. LWT, 124, p.109107.

[5] deShazo, R.D., Bigler, S. and Skipworth, L.B., 2013. The autopsy of chicken nuggets reads

[DOI: 10.22034/FSCT.22.159.316]

"chicken little". The American Journal of Medicine, 126(11), pp.1018-1019.
[6] Ağçam, E., 2022. Modeling of the changes in some physical and chemical quality attributes of potato chips during frying process. Applied Food Research, 2(1), p.100064.
[7] Pirsa, S. and Hafezi, K., 2023. Hydrocolloids: Structure, preparation method, and application in food industry. Food Chemistry, 399, p.133967.
[8] Ghaitaranpour, A., Mohebbi, M., Koocheki, A. and Ngadi, M.O., 2020. An agent-based coupled heat and water transfer model for air frying of doughnut as a heterogeneous multiscale porous material. Innovative Food Science & Emerging Technologies, 61, p.102335.
[9] Zaghi, A.N., Barbalho, S.M., Guiguer, E.L. and Otoboni, A.M., 2019. Frying process: From conventional to air frying technology. Food Reviews International, 35(8), pp.763-777.
[10] Wang, Y., Wu, X., McClements, D.J., Chen, L., Miao, M. and Jin, Z., 2021. Effect of new frying technology on starchy food quality. Foods, 10(8), p.1852
[11] Oke, E.K., Idowu, M.A., Sobukola, O.P., Adeyeye, S.A.O. and Akinsola, A.O., 2018. Frying of food: a critical review. Journal of Culinary Science & Technology, 16(2), pp.107-127.
[12] Liberty, J.T., Dehghannya, J. and Ngadi, M.O., 2019. Effective strategies for reduction of oil content in deep-fat fried foods: A review. Trends in Food Science & Technology, 92, pp.172-183.
[13] Xie, D., Guo, D., Guo, Z., Hu, X., Luo, S. and Liu, C., 2022. Reduction of oil uptake of fried food by coatings: A review. International Journal of Food Science & Technology, 57(6), pp.3268-3277.
[14] Dehghannya, J. and Ngadi, M., 2021. Recent advances in microstructure characterization of fried foods: Different frying techniques and process modeling. Trends in Food Science & Technology, 116, pp.786-801.
[15] Devi, S., Zhang, M., Ju, R. and Bhandari, B., 2021. Recent development of innovative methods for efficient frying technology. Critical Reviews in Food Science and Nutrition, 61(22), pp.3709-3724.
[16] Gouyo, T., Rondet, É., Mestres, C., Hofleitner, C. and Bohuon, P., 2021. Microstructure analysis of crust during deep-fat or hot-air frying to understand French fry texture. Journal of Food Engineering, 298, p.110484.
[17] Ghaitaranpour, A., Mohebbi, M. and Koocheki, A., 2021. An innovative model for describing oil penetration into the doughnut crust during hot air frying. Food Research International, 147, p.110458.
[18] Negara, B.F.S.P., Lee, M.J., Tirtawijaya, G., Cho, W.H., Sohn, J.H., Kim, J.S. and Choi, J.S., 2021. Application of deep, vacuum, and air frying methods to fry chub mackerel (Scomber japonicus). Processes, 9(7), p.1225.
[19] Cao, Y., Wu, G., Zhang, F., Xu, L., Jin, Q., Huang, J. and Wang, X., 2020. A comparative study of physicochemical and flavor characteristics of chicken nuggets during air frying and deep frying. Journal of the American Oil Chemists' Society, 97(8), pp.901-913.
[20] Castro-López, R., Mba, O. I., Gómez-Salazar, J. A., Cerón-García, A., Ngadi, M. O., & Sosa-Morales, M. E. (2023). Evaluation of chicken nuggets during air frying and deep-fat frying at different temperatures. International Journal of Gastronomy and Food Science, 31, 100631.
[21] He, D.B., Xu, F.E.I., Hua, T.C. and Song, X.Y., 2013. Oil absorption mechanism of fried food during cooling process. Journal of Food Process Engineering, 36(4), pp.412-417
[22] Fiszman, S.M. and Salvador, A., 2003. Recent developments in coating batters. Trends in food science & technology, 14(10), pp.399-407.
[23] Krupa-Kozak, U., Troszyńska, A., Bączek, N. and Soral-Śmietana, M., 2011. Effect of organic calcium supplements on the technological characteristic and sensory properties of gluten-free bread. European food research and technology, 232(3), pp.497-508.
[24] GIRI, N.A., Sheriff, J.T., Sajeev, M.S. and Pradeepika, C., 2016. Development and physico-nutritional evaluation of sweet potato flour based gluten free cookies. Journal of Root Crops, 42(1), pp.74-81.
[25] Gupta, M. and Bansal, V., 2021. Development of gluten free snacks using chickpea flour and flax seeds for celiac patients. Journal of Emerging Technologies and Innovative Research, 8, pp.223-238.
[26] Puerta, P., Laguna, L., Villegas, B., Rizo, A., Fiszman, S. and Tárrega, A., 2020. Oral processing and dynamics of texture perception in commercial gluten-free breads. Food Research International, 134, p.109233
[27] Kahlon, T.S., Avena-Bustillos, R.J. and Chiu, M.C.M., 2016. Sensory evaluation of gluten-free quinoa whole grain snacks. Heliyon, 2(12), p.e00213.
[28] Sabikun, N., Bakhsh, A., Rahman, M.S., Hwang, Y.H. and Joo, S.T., 2021. Evaluation of chicken nugget properties using spent hen meat added with milk fat and potato mash at different levels. Journal of food science and technology, 58(7), pp.2783-2791.
[29] Pinkaew, P. and Naivikul, O., 2019. Development of gluten-free batter from three Thai rice cultivars and its utilization for frozen battered chicken nugget. Journal of food science and technology, 56(8), pp.3620-3626.
[30] El-Sohaimy, S.A., El-Wahab, A., Miral, G., Oleneva, Z.A. and Toshev, A.D., 2022.

Physicochemical, Organoleptic Evaluation and Shelf Life Extension of Quinoa Flour-Coated Chicken Nuggets. Journal of Food Quality, 2022.
[31] Faloye, O.R., Sobukola, O.P., Shittu, T.A. and Bakare, H.A., 2021. Influence of frying parameters and optimization of deep fat frying conditions on the physicochemical and textural properties of chicken nuggets from FUNAAB-alpha broilers. SN Applied Sciences, 3(2), pp.1-17.
[32] AOAC (2000) Official methods of analysis of the association of analytical chemists. AOAC, Washington, DC
[33] Rahimi, D., Hasani, M. and Kashaninejad, M., 2021. Effects of Infrared cooking techniques and Balangu (Lallemantia royleana) gum concentration on quality characteristics and stress relaxation of chicken nugget. Journal of Food and Bioprocess Engineering, 4(1), pp.26-36.
[34] Pinkaew, P. and Naivikul, O., 2019. Development of gluten-free batter from three Thai rice cultivars and its utilization for frozen battered chicken nugget. Journal of food science and technology, 56(8), pp.3620-3626.
[35] Akdeniz, N., Sahin, S., Sumnu, G. 2006. Functionality of batters containing different gums for deep-fat frying of carrot slices. J Food Eng, 75:522–6.
[36] Albert, A., Perez-Munuera, I., Quiles, A., Salvador, A., Fiszman, S.M., and Hernando, I. 2009. Adhesion in fried battered nuggets: Performance of different hydrocolloids as predusts using three cooking procedures. Food Hydrocolloids, 23: 1443–1448
[37] Chayawat, J. and Rumpaporn, P., 2020. Reducing chicken nugget oil content with fortified defatted rice bran in batter. Food Science and Biotechnology, 29(10), pp.1355-1363.
[38] Udomkun, P., Niruntasuk, P. and Innawong, B., 2019. Impact of novel far-infrared frying technique on quality aspects of chicken nuggets and frying medium. Journal of Food Processing and Preservation, 43(5),p.e13931.
[39] Vélez-Ruiz, J. F., & Sosa-Morales, M. E. (2003). Evaluation of physical properties of dough of donuts during deep-fat frying at different temperatures. International Journal of Food Properties, 6(2), 341-353.
[40] Ghaitaranpour, A., Mohebbi, M., & Oleyaei, S. A. (2024). Effects of coating formulation on structural changes of turkey nugget during frying: MRI evaluation. Journal of Future Foods, 4(2), 142-148.
[41] Ghaitaranpour, A., Koocheki, A., Mohebbi, M. and Ngadi, M.O., 2018. Effect of deep fat and hot air frying on doughnuts physical properties and kinetic of crust formation. Journal of Cereal Science, 83, pp.25-31.
[42] Santos, C. S., Cunha, S. C., & Casal, S. (2017). Deep or air frying? A comparative study with different vegetable oils. European Journal of Lipid Science and Technology, 119(6), 1600375.
[43] Teruel, M. D. R., Gordon, M., Linares, M. B., Garrido, M. D., Ahromrit, A., & Niranjan, K. (2015). A comparative study of the characteristics of french fries produced by deep fat frying and air frying. Journal of Food Science, 80(2), E349-E358.
[44] Andrés, A., Arguelles, A., Castelló, M. L., & Heredia, A. (2013) Mass transfer and volume changes in French fries during air frying. Food and Bioprocess Technology, 6:1917–1924. https://doi.org/10.1007/ s11947-012-0861-2.
[45] Conte, P., Pulina, S., Del Caro, A., Fadda, C., Urgeghe, P. P., De Bruno, A., ... & Piga, A. (2021). Gluten-free breadsticks fortified with phenolic-rich extracts from olive leaves and olive mill wastewater. Foods, 10(5), 923.
[46] Pan, G., Ji, H., Liu, S., & He, X. (2015). Vacuum frying of breaded shrimps. LWT-Food Science and Technology, 62(1), 734-739.
[47] Jan, K. N., Panesar, P. S., & Singh, S. (2018). Textural, in vitro antioxidant activity and sensory characteristics of cookies made from blends of wheat-quinoa grown in I ndia. Journal of Food Processing and Preservation, 42(3), e13542.
[48] Sansano, M., Juan-Borrás, M., Escriche, I., Andrés, A., & Heredia, A. (2015). Effect of pretreatments and air-frying, a novel technology, on acrylamide generation in fried potatoes. Journal of food science, 80(5), T1120-T1128.
[49] Manjunatha, S. S., Ravi, N., Negi, P. S., Raju, P. S., & Bawa, A. S. (2014). Kinetics of moisture loss and oil uptake during deep fat frying of Gethi (Dioscorea kamoonensis Kunth) strips. Journal of food science and technology, 51, 3061-3071.
[50] Moss, R., & McSweeney, M. B. (2022). Effect of quinoa, chia and millet addition on consumer acceptability of gluten-free bread. International Journal of Food Science & Technology, 57(2), 1248-1258.
[51] Gostin, A. I. (2019). Effects of substituting refined wheat flour with wholemeal and quinoa flour on the technological and sensory characteristics of salt-reduced breads. LWT, 114, 108412.

[DOI: 10.22034/FSCT.22.159.316]

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

بررسی اثر روش سرخ کردن و فرمولاسیون خمیرابه بر ویژگی‌های فیزیکوشیمیایی ناگت مرغ

زلیخا فحیمی واجارگاهی[1]، محسن اسمعیلی[2*]، آرش قیطران‌پور[2]

۱- دانشجوی کارشناسی ارشد گروه علوم و مهندسی صنایع غذایی دانشگاه ارومیه ـ ایران

۲- گروه علوم و صنایع غذایی، دانشگاه ارومیه، ارومیه - ایران

اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱٤۰۳/٦/۲۵

تاریخ پذیرش: ۱٤۰۳/۹/۲۱

کلمات کلیدی:

خمیرابه بدون گلوتن،

ناگت مرغ،

سرخ کن عمیق،

سرخ کن هوای داغ،

ویژگی فیزیکوشیمیایی

DOI:10.22034/FSCT.22.159.316.

* مسئول مکاتبات:

m.esmaiili@urmia.ac.ir

چکیده

ناگت مرغ بعنوان یکی از پرطرفدارترین غذاهای آماده مصرف، به روش عمیق سرخ می شود. به دلیل غوطه وری محصول در روغن، محتوای چربی آن افزایش می یابد در نتیجه می تواند باعث ایجاد چاقی و بیماری های مرتبط با آن شود. به همین دلیل کاهش چربی محصول با حفظ خواص ارگانولپتیکی بسیار مورد توجه و بررسی محققاق قرار گرفته است. در این مطالعه ناگت های مرغ با فرمولاسیون متفاوت خمیرابه (آرد گندم، آرد برنج و آرد کینوا) به دو روش (عمیق و هوای داغ) سرخ شدند و از نظر محتوای رطوبت، محتوای روغن، کاهش وزن، میزان جذب خمیرابه، درصد چسبندگی، رنگ، بافت، قطر و ارزیابی حسی مورد بررسی قرار گرفتند. محتوای روغن، رطوبت و درصد چسبندگی پوشش به بستر محصول به روش سرخ کردن عمیق بیشتر از سرخ کردن هوای داغ بود. بافت ناگت های مرغ سرخ شده به روش عمیق دارای سفتی کمتری بودند. نتایج نشان داد که نمونه های پوشش داده شده با آرد کینوا محتوای رطوبت و جذب خمیرابه بالاتری نسبت به نمونه های پوشش داده شده با آرد برنج و گندم داشتند، در حالیکه محتوای روغن، کاهش وزن و چسبندگی پوشش به بستر آنها کمتر بود. از نظر رنگ، پوشش خمیرابه کینوا *L، *b ، زاویه Hue پایین‌تر و *a بالاتری را نشان داد. میزان سفتی ناگت‌های مرغ پوشش داده شده با خمیرابه کینوا پایین تر از دو نمونه دیگر بود. نتایج نشان داد که سرخ کردن هوای داغ به طور کلی روش سالمی برای تولید ناگت مرغ و جایگزین ارزشمندی برای تولید غذاهای پروتئینی سرخ شده است. خمیرابه آرد کینوا بعنوان غله ی فاقد گلوتن با ارزش تغذیه ای بالا می تواند جایگزینی برای گندم بوده و در کاهش محتوای روغن فراورده های سرخ شده موثر باشد.