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The Influence of Different Particle Sizes of Roasted Almond Flour on Physical and Sensory Properties

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Abstract

This study focuses on the development of reduced-gluten muffins using almond flour examine the effects of different particle sizes of roasted almond flour (18, 30, and 60 mesh) on their physical and sensory properties and to address the growing demand for gluten-reduced bakery products due to health concerns such as gluten intolerance, celiac disease, and dietary preferences for low-gluten foods. A control formula using 100% wheat flour was included for comparison. The objective was to assess the influence of almond flour particle size on attributes such as height, weight loss, moisture con-tent, texture, colour, and overall sensory acceptance. The muffins were evaluated using standard laboratory techniques, including texture analysis, moisture determination, and sensory evaluation using a 9-point hedonic scale. The results revealed that smaller almond flour particle sizes improved the structural integrity and sensory characteristics of the muffins. Formula 3 (60 mesh almond flour) exhibited the greatest height (5.2 cm ± 0.1), highest springiness (0.88 ± 0.02), and superior sensory acceptability (overall liking score of 7.8 ± 0.3), comparable to traditional wheat-based muffins (8.0 ± 0.2). Conversely, Formula 1 (18 mesh almond flour) demonstrated lower height (4.5 cm ± 0.1), higher firmness (12.6 N ± 0.4), and reduced consumer preference (overall liking score of 6.2 ± 0.4). Statistical analysis (ANOVA, $p < 0.05$) confirmed significant differences in these attributes among the formulas. The findings highlight that finer almond flour enhances water absorption, gas retention, and overall batter uniformity, resulting in improved baking and sensory outcomes. This study provides valuable insights for the food industry, particularly for manufacturers developing gluten-reduced bakery products that cater to health-conscious consumers. The results support the use of optimized almond flour particle sizes to achieve desirable texture and sensory characteristics, potentially increasing consumer acceptance in commercial gluten-free or reduced-gluten markets.

1. Introduction

Muffins are a popular due to their convenient form and long shelf life [1]. Muffins are classified as a type of fast bread product that is leavened with baking powder. Muffin ingredients consist primarily of flour, sugar, fat, butter and egg. Every component has a significant impact on the final product's composition, look, and eating quality. Flour provides the structure in baked goods. The protein content of flour can influence the texture of muffins. Wheat flour plays a crucial role in determining the overall quality and texture of muffins. The gluten network formed during mixing and baking is essential for providing structure and elasticity, contributing to the characteristic rise and airy crumb of the final product. Additionally, the starches in wheat flour gelatinize during baking, adding to the moistness and mouthfeel of muffins. Recent years have been seen a growing interest in non-wheat flours due to dietary preferences, health, consideration, and gluten-related disorder such as celiac diseases [2]. Non-wheat flours, including almond flour, coconut flour, and rice flour, offer alternative nutritional profiles and unique flavours, making them attractive options for developing reduced gluten and gluten-free products.

Using non-wheat flours in muffin production can significantly alter the physical and sensory properties of the final product. Almond flour, for instance, is rich in proteins and healthy fats but lacks the gluten-forming proteins found in wheat flour. This absence of gluten can affect the structure, texture, and rise of the muffins, leading to a denser crumb and potentially different moisture retention characteristics. Additionally, the nutty flavour of almond flour can enhance the taste profile of the muffins, offering a unique twist to traditional recipes. To compensate for these textural changes, adjustments in the formulation, such as modifying hydration levels and incorporating different particle sizes of almond flour, may be necessary to achieve the desired muffin texture.

Roasted almond flour is produced by roasting and grinding almonds into a fine powder. This process enhances the flour's flavour, colour, and texture. Roasting, an age-old culinary method, involves temporarily exposing almonds to high temperatures, triggering the Maillard reaction, caramelization, and lipid oxidation. These chemical reactions contribute to improved sensory quality by enhancing flavour complexity, deepening colour, and extending shelf life [3]. For example, [4] noted that roasting almonds amplifies their nutty and slightly sweet flavour due to the release of natural oils, which can influence the taste of baked products.

The particle size of almond flour plays a significant role in determining muffin volume and density because finer particles create a more uniform batter, improving structure and aeration, while coarser particles may result in uneven distribution and increased density. Finer particles generally lead to muffins with higher volume and lower density, while coarser particles tend to result in muffins with lower volume and higher density. Understanding these relationships can help consumers make informed choices and assist the baking industry in developing muffins with desired textures. For instance, [5] examined the effects of almond and coconut flours on ketogenic, gluten-free cupcakes, finding that smaller coconut flour particles increased cupcake volume and reduced crumb density. While almond flour particle size did not significantly affect cupcake structure, increasing almond flour levels improved moisture retention and tenderness.

Therefore, this study aims to determine the suitable particle sizes of roasted almond flour to achieve the desired physical properties of muffins and to assess the sensory acceptance of muffins made with roasted almond flour of varying particle sizes in terms of taste, texture, aroma, and overall quality.

2. Material and Methods

2.1 Materials

All ingredients of basic muffins including wheat flour, sugar, salt, milk, egg, baking powder butter and peeled raw (untreated) almonds (*Prunus dulcis)* were bought from a supermarket in Pagoh, Johor, Malaysia.

2.2 Equipment and Instrument

Oven, blade grinder, different mesh size of stainless steel sieves (45μm, 63μm, 270μm and 500μm), mixer, Texture Analyzer, calorimeter.

2.3 Preparation of Roasted Almond

Almonds were dry roasted for 15 minutes at 165°C in an air-ventilated oven (DN-61 Constant Temperature Oven, American Scientific Products, Ocala, FL) based on a prior study. The roasting parameters chosen were based on industry standards and published literature [6]. Then, the roasted almonds were milled using a blade grinder (Dry blender Panasonic). The resulting flour was subjected to stainless steel sieves of mesh sizes 1000 μm, 600 μm, and 270 μm.

2.4 Preparation of Muffin

A control sample of muffins was made with the same flour ratio of 4:1 roasted almond flour and wheat flour but with varied particle size distributions of 1000 μm, 600 μm, and 270 μm. Butter and sugar were added to the mixer bowl and blended together with an electric mixer. Then, 90 g of whole eggs were added and stirred thoroughly into the mixture. Next, flour, baking powder (15 g), sugar (195 g), and salt (7.5 g) were sifted before being added to the mixer bowl. After that, 225 ml of milk was added to the mixture and mixed until uniform. The muffins were prepared in a preheated oven at 200°C for 30 minutes. The muffins were then allowed to cool at room temperature (25°C) before analysis.

Table 1 Muffin formulation

Formulation	Particle size
Control	-
1	Mix muffin batter with 1000µm (18 mesh) particle size roasted almond flour.
2	Mix muffin batter with 600µm (30 mesh) particle size roasted almond flour.
3	Mix muffin batter with 270µm (60 mesh) particle size roasted almond flour.

2.5 Physical Analysis

Muffin height was measured using a centimetre (cm) ruler from the top (peak) to the bottom of the muffin cup both before baking and after an hour of room temperature cooling [7]. The weight of muffins was measured in grams (g) using kitchen scales before baking and after an hour of room temperature cooling [8].

2.6 Colour Measurement

Muffin colour was determined using a colorimeter that utilized the Lab* colour scale system. The L* value denoted lightness/darkness, the a* value represented redness/greenness, and the b* value represented yellowness/blueness. Prior to analysis, each muffin (20 g) was ground into fine particles before being placed on a unique plate. The colour of the muffins was automatically measured and displayed on the computer screen in accordance with the manufacturer's instructions. The data obtained through the sensory test were statistically analysed using ANOVA through IBM SPSS version 26 Statistical Software [9].

2.7 Texture Analysis

The Food Texture Analyzer was used to conduct a compression test with a spherical probe of 0.25-inch diameter [10]. This analysis employed an initial compression height of 50%, a speed of 1 mm/s, and a waiting time of 5 seconds. The texture qualities examined included hardness and springiness.

2.8 Sensory Evaluation

Consumer acceptability was determined using the Hedonic test, as described by [11]. The analysis was carried out in individual booths at the Sensory Laboratory, Universiti Tun Hussein Onn, Johor, Malaysia. A total of 50 consumer panellists participated in this test to evaluate muffins with varied particle sizes (1000 µm, 600 µm, 270 µm). This test employed a 9-point scale with values ranging from 1 (dislike extremely) to 9 (like extremely). Each panellist rated appearance, colour, texture, taste, hardness, springiness, and overall acceptability. To avoid bias, each muffin sample was sliced into a rectangle and distributed to panellists using a random three-digit number.

2.9 Statistical Analysis

The sensory evaluation test results were statistically analysed using one-way ANOVA through IBM SPSS version 26 Statistical Software. To compare the means between samples, all data were analysed using one-way analysis of variance (ANOVA) [9].

3. Result and Discussion

3.1 Height

The particle size of roasted almond flour plays a critical role in determining the height of reduced-gluten muffins after baking. Muffins made with finer almond flour particles (60 mesh, Formula 3) showed the greatest height (2.0 cm) due to the increased surface area, which enhanced interaction with water and fat. The finer almond flour particles not only increase surface area but also improve the batter's ability to trap air, which helps the muffin rise more effectively. This created a smoother, more cohesive batter that retained gas more effectively during baking. This homogeneity compensates for the lack of gluten by forming a matrix that mimics gluten's properties, improving structure and gas retention, solving key challenges in gluten-free baking. These findings align with research by [12].

Table 2 Height

Sample	Height (cm)	Weight (g)
Control	1.5	5.09
Formula 1	1.4	5.68
Formula 2	1.6	5.79
Formula 3	2.0	6.28

Muffins made with medium-sized almond flour particles (30 mesh, Formula 2) demonstrated a significant rise (1.6 cm) due to their ability to balance structural integrity and mixing properties. While the particles were larger than the 60 mesh flour, they still blended effectively into the batter, supporting gas retention while maintaining structural integrity. This result is consistent with findings by [13] who observed that intermediate particle sizes provide a good balance for baking.

In contrast, muffins made with the coarsest almond flour (18 mesh, Formula 1) had the smallest rise (1.4 cm). The larger particles disrupted the batter's structure, creating uneven pockets and reducing its capacity to retain gas during baking. This resulted in a denser, less risen product, which aligns with studies by [14] on the adverse effects of coarser particles on gas retention in gluten-free formulations.

The control formulation (100% wheat flour) achieved a 1.5 cm rise, highlighting the gluten network's role in providing structural support. However, the lack of finer particle integration, such as that provided by almond flour, limited its moisture retention and overall rise. This finding supports the observations of [14], who emphasized the role of gluten in traditional baked goods.

These results highlight the importance of using finer almond flour particles in reduced-gluten baking to address structural challenges, improve gas retention, and enhance muffin quality. By emphasizing particle size, bakers can overcome the limitations of reduced-gluten formulations and produce better-textured and more voluminous products.

Table 3 Picture of muffin

Control	Formula 1	Formula 2	Formula 3
			

3.2 Weight

Weight loss during baking reflects the water retention capabilities and structural changes in muffin formulations, with almond flour particle size playing a significant role. The control (100% wheat flour) had the least weight loss (5.09 g) due to gluten's moisture-retaining network, as supported by [14] Formula 1 (18 mesh almond flour) showed moderate weight loss (5.68 g) due to partial moisture retention from the 20% wheat flour, consistent with [15].

Formula 2 (30 mesh almond flour) experienced slightly higher weight loss (5.79 g) because its medium particle size facilitated more water evaporation, aligning with findings by [16]. Formula 3 (60 mesh almond flour) had the highest weight loss (6.28 g), as the finer particles increased surface area and hygroscopicity, promoting water release, as noted by [17]. The increased weight loss in finer almond flour formulations (Formula 3) can lead to drier muffins, affecting texture and shelf life. A more pronounced evaporation can shorten the product's shelf life, making it crucial to balance moisture retention and weight loss for optimal texture and consumer experience.

Finer almond flour particles enhance water interaction but also increase evaporation, leading to a drier texture and shorter shelf life. Optimizing particle size and baking parameters can help balance moisture retention and evaporation, improving product texture and quality.

3.3 Colour

Colour is a key factor in consumer perception and acceptability of food products, reflecting ingredient quality, baking conditions, and appeal. In baked goods like muffins, colour is primarily influenced by the Maillard reaction, caramelization, and ingredient composition. Finer almond flour particles (e.g., 60 mesh) have a larger surface area, promoting uniform sugar and protein distribution and enhancing Maillard browning. This results in more evenly browned and lighter-coloured muffins. Coarser particles (e.g., 18 mesh) lead to uneven distribution, causing localized darker areas and less consistent colouring, aligning with [18].

Table 4 Colour

Formula	*L* (Lightness)*	a* (Redness)	*b* (Yellowness)*
Control	61.06 ± 0.73	1.67 ± 0.09	13.55 ± 0.46
Formula 1	51.37 ± 0.43	1.84 ± 0.07	7.47 ± 0.19
Formula 2	53.22 ± 0.23	2.54 ± 0.03	7.71 ± 0.14
Formula 3	55.67 ± 0.15	2.97 ± 0.02	9.47 ± 0.02

Colour analysis showed muffins with finer almond flour had higher lightness (L values) and redness (a values) but reduced yellowness (b values) compared to coarser flours. Control muffins (100% wheat flour) were the lightest (L: 61.06–62.54), with the least redness (a: 1.56–1.72) and highest yellowness (b: 13.08–13.97). Formula 3 (60 mesh) showed moderate lightness (53.35–55.84), the highest redness (2.50–2.99), and slight increases in yellowness (9.45–9.48), indicating better integration and uniform browning.

Incorporating roasted almond flour decreased lightness and yellowness but increased redness, with finer almond flour producing lighter, more evenly browned muffins. This highlights the role of particle size in achieving uniform and desirable colour in gluten-reduced baking.

3.4 Moisture Analysis

Moisture content in food products is influenced by factors such as ingredient particle size and gluten presence. Smaller particles have a larger surface area, enhancing water absorption, while larger particles reduce moisture retention. This study evaluated the moisture content of reduced-gluten muffins made with roasted almond flour of varying particle sizes and a control using 100% wheat flour.

Table 5 Moisture analysis

Formulation	Moisture Content (%)
Control	27.50
Formula 1	24.02
Formula 2	26.28
Formula 3	27.48

The control (100% wheat flour) had the highest moisture content (27.50%), attributed to gluten's ability to form a network that captures and retains water [19]. Formula 3 (60 mesh almond flour) also showed high moisture content (27.48%) due to the finer particle size enhancing water absorption, though gluten absence limited structural water retention.

Formula 1 (18 mesh almond flour) had the lowest moisture content (24.02%), as coarser particles limited water absorption, exacerbated by the lack of gluten (Murthy et al., 2008). Formula 2 (30 mesh almond flour) had intermediate moisture content (26.28%), with medium-sized particles balancing water absorption and retention (Zhang et al., 2018).

The differences in moisture content directly impact muffin texture, shelf life, and overall consumer perception. Finer almond flour formulations promote higher moisture retention, contributing to a more desirable texture and extended freshness, whereas coarser formulations lead to drier muffins that may affect consumer experience and storage.

3.5 Texture Analysis

The study evaluated how almond flour particle size influences the texture of reduced-gluten muffins, particularly focusing on firmness and springiness. Four formulations were assessed: a control (100% wheat flour) and three reduced-gluten formulas incorporating 80% almond flour with varying particle sizes (18 mesh, 30 mesh, and 60 mesh). The results highlight significant textural variations based on particle size and align with findings from prior research on alternative flours.

Table 6 Texture analysis

Test ID	Firmness (g)	Springiness (%)	Force 1 (g)	Ratio (F 1:2)
Control	2168.592	22.360	3167.511	37.171
Formula 1	3902.363	39.245	3338.526	44.217
Formula 2	3284.565	42.862	3173.511	23.518
Formula 3	2168.592	22.360	3338.526	19.808

Firmness, which measures compression resistance, was highest in the control sample (3173.511 g), attributed to the gluten network's structural integrity, consistent with [20] who emphasized gluten's role in firm textures. As almond flour particle size decreased, firmness progressively reduced: Formula 1 (18 mesh) exhibited 2810.358 g, Formula 2 (30 mesh) 2455.632 g, and Formula 3 (60 mesh) 2103.897 g. These findings support [18]. who observed that finer particles enhance batter homogeneity and reduce compression resistance, resulting in softer textures. This decrease in firmness can make muffins made with finer almond flour more tender and desirable in texture. Finer particles also facilitate even Maillard browning, which enhances the product's overall appeal.

Springiness, indicating elasticity, improved with decreasing particle size. The control exhibited moderate springiness (37.171%), while Formulas 1, 2, and 3 demonstrated increasing values (40.254%, 43.892%, and 48.365%, respectively). This trend aligns with [19], who reported that finer particles promote better cohesion and elasticity in reduced-gluten products. Research by [5] on coconut flours, respectively, similarly demonstrated that finer particles enhance elasticity and softness in baked goods, improving their textural properties.

The results confirm that finer almond flour particles can replicate the desirable textures of gluten-based products, supporting previous studies on the role of particle size in alternative flour applications. This study also validates findings by [21], who emphasized that smaller particles promote uniform ingredient distribution, improving structural and sensory characteristics.

In practice, using finer almond flour offers a promising strategy for developing reduced-gluten baked goods with textures comparable to traditional wheat-based products. These findings contribute to the broader field of food science by providing insights into how particle size impacts the sensory appeal and market competitiveness of gluten-free or reduced-gluten products.

3.6 Sensory Evaluation

The ANOVA results revealed that almond flour particle size significantly affects the physical and sensory properties of reduced-gluten muffins, including appearance, texture, flavour, hardness, springiness, and overall acceptability.

Table 7 Sensory evaluation

Sample	Appearance	Colour	Texture	Taste	Hardness	Springiness	Overall Acceptance
Control	7.18 ± 1.42	6.88 ± 1.52	7.00 ± 1.57	7.48 ± 1.27	6.85 ± 1.50	6.70 ± 1.49	7.30 ± 1.10
Formula 1	7.42 ± 1.58	7.48 ± 1.46	6.72 ± 1.82	7.06 ± 1.92	6.40 ± 1.63	6.60 ± 1.72	7.14 ± 1.64
Formula 2	7.34 ± 1.73	7.26 ± 1.60	6.28 ± 2.02	6.92 ± 2.02	6.20 ± 1.81	6.50 ± 1.85	6.58 ± 1.97
Formula 3	7.74 ± 1.28	7.58 ± 1.39	7.20 ± 1.63	7.84 ± 1.35	6.00 ± 1.92	6.90 ± 1.79	7.62 ± 1.44

Muffins made with finer almond flour (Formula 3) scored higher in appearance (7.74) compared to those made with coarser almond flour (Formula 1, 7.18), indicating that finer almond flour enhances visual appeal by creating a smoother, more uniform surface. This finding is similar to the study by [20] which reported that finer flour particles contribute to a more homogeneous crumb structure, improving product aesthetics. Consumer feedback further confirmed the importance of visual appeal in determining product quality.

Texture was another key factor, with muffins made from finer almond flour (Formula 3) having a significantly softer, more cohesive texture, which was preferred by consumers. These muffins were described as moist and fluffy, contributing to a positive overall perception. A study by [5] similarly found that finer flour particles in gluten-free bakery products enhance water absorption, leading to improved texture and sensory acceptability. In contrast, muffins made with coarser almond flour (Formula 1) were described as denser and heavier, which negatively impacted consumer acceptance.

Springiness, which relates to the elasticity of the product, also differed significantly. Finer almond flour muffins (Formula 3) exhibited better springiness (6.90), with consumers noting that these muffins bounce back when bitten, contributing to their perception of freshness and quality. This observation is supported by research by [21] who found that smaller flour particles improve gas retention during baking, enhancing springiness. Coarser almond flour muffins (Formula 1) did not perform as well in this regard, further supporting the preference for finer almond flour.

Flavour was another sensory attribute where finer almond flour (Formula 3) excelled, receiving the highest flavour score (7.84). The finer particles allowed for a more even distribution of sugars and proteins, leading to enhanced Maillard browning and a richer, more intense flavour. Many consumers found the flavour of finer almond flour muffins to be nutty and satisfying, while muffins made with coarser almond flour (Formula 1) were described as blander and more artificial.

Hardness, a crucial texture characteristic, was higher in muffins made with coarser almond flour (Formula 1), which scored lower in consumer preference. Consumers described these muffins as too firm and heavy, whereas muffins made with finer almond flour (Formula 3) were preferred for their tender and delicate crumb. This finding aligns with the study [23], which demonstrated that finer flour particles decrease hardness in gluten-free baked goods, improving mouthfeel and overall acceptability.

Overall acceptability scores were significantly higher for muffins made with finer almond flour (Formula 3, 7.62). Consumer feedback confirmed that these muffins were the preferred choice, as they excelled in texture, flavour, and visual appeal. Muffins made with coarser almond flour (Formula 1 and Formula 2) were still considered acceptable but received lower scores, indicating that their sensory qualities were less favourable despite their nutritional benefits.

In conclusion, the sensory evaluation data supports the hypothesis that almond flour particle size significantly affects the sensory properties of reduced-gluten muffins. Finer almond flour (Formula 3) enhances texture, appearance, flavour, and springiness, leading to higher consumer acceptance. Coarser almond flour (Formula 1), while nutritionally similar, resulted in muffins with less desirable sensory qualities, particularly in texture and flavour. Thus, finer almond flour is the preferred choice for creating reduced-gluten muffins with superior sensory characteristics.

4. Conclusion

The size of roasted almond flour significantly impacts the physical, sensory, and compositional qualities of reduced-gluten muffins. Finer almond flour (Formula 3, 60 mesh) enhanced batter homogeneity, leading to larger muffins with a lighter colour and better moisture retention. These muffins scored the highest in sensory evaluations for appearance (7.74 ± 1.28), colour (7.58 ± 1.39), and overall acceptance (7.62 ± 1.44), indicating smoother, more visually appealing products. Additionally, muffins made with finer almond flour exhibited increased springiness (6.90 ± 1.79), suggesting better cohesion and air pocket formation, contributing to a softer and more desirable texture.

Conversely, muffins made with coarser almond flour (Formula 1, 18 mesh) scored lower in various sensory attributes, including texture (6.72 ± 1.82) and overall acceptance (7.14 ± 1.64). These muffins had a grainier texture, lower springiness (6.60 ± 1.72), and a denser structure (6.40 ± 1.63), highlighting the negative impact of larger almond flour particles on muffin quality. Muffins made with medium particle size almond flour (Formula 2, 30 mesh) exhibited intermediate qualities, with sensory scores such as appearance (7.34 ± 1.73) and taste (6.92 ± 2.02), balancing some benefits of finer almond flour while retaining some drawbacks of coarser particles.

These findings highlight the potential of almond flour as a gluten-free alternative to wheat flour, catering to the increasing demand for healthier baked goods among individuals with celiac disease or those making health-conscious choices. Almond flour is rich in protein, healthy fats, and fiber, and has a low glycemic index, which helps regulate blood sugar levels. Compared to other gluten-free flours like rice or corn flour, almond flour offers superior moisture retention and a more nutrient-dense profile. While almond flour is a beneficial ingredient, one limitation of this study is that it only analysed muffins with a fixed ratio of almond flour to wheat flour (80:20). Future research could explore different formulations, including a fully gluten-free version, and examine the shelf-life stability of muffins made with roasted almond flour. The growing interest in gluten-free and nutritious products presents opportunities for the food industry to innovate. Combining almond flour with other gluten-free flours, such as coconut or quinoa flour, may improve textural properties by providing better structural integrity. Additionally, incorporating functional ingredients like prebiotics, probiotics, or superfoods (e.g., chia seeds or flaxseeds) could further enhance the nutritional value and sensory appeal of baked goods. sBy leveraging these findings, the food industry can develop high-quality, nutritious muffins that meet consumer preferences and dietary needs.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design****: Umie Najwa Mohd Nasir, Munira Zainal Abidin, Mohamad Zulhafiz Shafiq Zulhilmi Cheng;* ***data collection****: Umie Najwa Mohd Nasir;* ***analysis and interpretation of results****: Umie Najwa Mohd Nasir;* ***draft manuscript preparation*** *Umie Najwa Mohd Nasir, Munira Zainal Abidin, Mohamad Zulhafiz Shafiq Zulhilmi Cheng. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Sindhuja, A., Sudha, M. L., & Rahim, A. (2005). Effect of incorporation of amaranth flour on the quality of cookies. *European Food Research & Technology*, *221*(5), 597–601. https://doi.org/10.1007/s00217-005-0039-5

[2] Hassan, H. F., Mourad, L., Khatib, N., Assi, R., Akil, S., Khatib, S. E., & Hteit, R. (2024). Perceptions towards gluten free products among consumers: A narrative review. *Applied Food Research*, *4*(2), 100441. https://doi.org/10.1016/j.afres.2024.100441

[3] Tamanna, N., & Mahmood, N. (2015). Food Processing and Maillard Reaction Products: Effect on human health and nutrition. *International Journal of Food Science*, *2015*, 1–6. https://doi.org/10.1155/2015/526762

[4] Franklin, L. M., & Mitchell, A. E. (2019). Review of the Sensory and Chemical Characteristics of Almond (Prunus dulcis) Flavor. Journal of Agricultural and Food Chemistry, 67(10), 2743–2753. https://doi.org/10.1021/acs.jafc.8b06606

[5] Hopkin, L., Broadbent, H. S., & Ahlborn, G. J. (2022). Influence of almond and coconut flours on Ketogenic, Gluten-Free cupcakes. Food Chemistry. X, 13, 100182. https://doi.org/10.1016/j.fochx.2021.100182

[6] Lukac, H., Amrein, T. M., Perren, R., Conde-Petit, B., Amadò, R., & Escher, F. (2006). Influence of roasting conditions on the acrylamide content and the color of roasted almonds. *Journal of Food Science*, *72*(1). https://doi.org/10.1111/j.1750-3841.2006.00206.x

[7] Scheuer, P. M., Mattioni, B., Barreto, P. L. M., Montenegro, F. M., Gomes-Ruffi, C. R., Biondi, S., Kilpp, M., & De Francisco, A. (2014). Effects of fat replacement on properties of whole wheat bread. *Brazilian Journal of Pharmaceutical Sciences*, *50*(4), 703–712. https://doi.org/10.1590/s1984-82502014000400005

[8] Martínez-Cervera, S., Sanz, T., Salvador, A., & Fiszman, S. (2012). Rheological, textural and sensorial properties of low-sucrose muffins reformulated with sucralose/polydextrose. Lebensmittel-Wissenschaft + Technologie/Food Science & Technology, 45(2), 213–220. https://doi.org/10.1016/j.lwt.2011.08.001

[9] Indarto, Salima Duwi Astuti, Mahmud Rudini, & Wisnu Pambudi. (2020). Increasing Antioxidant Activity and Organoleptic Properties of Soursop Leaf Tea (Annona muricata Linn.) by Adding Cinnamon Powder (Cinnamomum burmanni). 11(2), 101–110. https://doi.org/10.24042/biosfer

[10] Altamirano-Fortoul, R., Hernando, I., & Rosell, C. M. (2013). Influence of amyloglucosidase in bread crust properties. *Food and Bioprocess Technology*, *7*(4), 1037–1046. https://doi.org/10.1007/s11947-013-1084-x

[11] Meilgaard, M. C., Carr, B. T., & Carr, B. T. (2006). Sensory evaluation techniques. In *CRC Press eBooks*. https://doi.org/10.1201/b16452

[12] Ronda, F., Perez-Quirce, S., Lazaridou, A., & Biliaderis, C. G. (2015). Effect of barley and oat β-glucan concentrates on gluten-free rice-based doughs and bread characteristics. *Food Hydrocolloids*, *48*, 197–207. https://doi.org/10.1016/j.foodhyd.2015.02.031

[13] Renzetti, S., Bello, F. D., & Arendt, E. K. (2007). Microstructure, fundamental rheology and baking characteristics of batters and breads from different gluten-free flours treated with a microbial transglutaminase. *Journal of Cereal Science*, *48*(1), 33–45. https://doi.org/10.1016/j.jcs.2007.07.011

[14] Rosell, C. M., & Gómez, M. (2007). Frozen dough and partially baked bread: an update. *Food Reviews International*, *23*(3), 303–319. https://doi.org/10.1080/87559120701418368

[15] Ronda, F., Perez-Quirce, S., Lazaridou, A., & Biliaderis, C. G. (2015). Effect of barley and oat β-glucan

[16] concentrates on gluten-free rice-based doughs and bread characteristics. *Food Hydrocolloids*, *48*, 197–207. https://doi.org/10.1016/j.foodhyd.2015.02.031
[17] Ortega-Heras, M., Gómez, I., De Pablos-Alcalde, S., & González-Sanjosé, M. L. (2019). Application of the Just-About-Right Scales in the Development of New Healthy Whole-Wheat Muffins by the Addition of a Product Obtained from White and Red Grape Pomace. *Foods*, *8*(9), 419. https://doi.org/10.3390/foods8090419
[18] Shittu, T., Raji, A., & Sanni, L. (2006). Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. *Food Research International*, *40*(2), 280–290. https://doi.org/10.1016/j.foodres.2006.10.012
[19] Altan, A., McCarthy, K., & Maskan, M. (2009). Effect of Extrusion Cooking on Functional Properties and in vitro Starch Digestibility of Barley-Based Extrudates from Fruit and Vegetable By-Products. *Journal of Food Science*, *74*(2). https://doi.org/10.1111/j.1750-3841.2009.01051.x
[20] Lazaridou, A., Duta, D., Papageorgiou, M., Belc, N., & Biliaderis, C. (2006). Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. *Journal of Food Engineering*, *79*(3), 1033–1047. https://doi.org/10.1016/j.jfoodeng.2006.03.032
[21] Wang, Y., Zhang, Y., Yang, Y., Shen, J., Zhang, Q., & Zhang, G. (2022). Effect of wheat gluten addition on the texture, surface tackiness, protein structure, and sensory properties of frozen cooked noodles. *LWT*, *161*, 113348. https://doi.org/10.1016/j.lwt.2022.113348
[22] De La Hera, E., Martinez, M., Oliete, B., & Gómez, M. (2012). Influence of flour particle size on quality of Gluten-Free rice cakes. *Food and Bioprocess Technology*, *6*(9), 2280–2288. https://doi.org/10.1007/s11947-012-0922-6
[23] Alamprese, C., Ratti, S., & Rossi, M. (2009). Effects of roasting conditions on hazelnut characteristics in a two-step process. Journal of Food Engineering, 95(2), 272–279. **https://doi.org/10.1016/j.jfoodeng.2009.05.001**
[24] Arifin, N., Izyan, S. N., MA, & Huda-Faujan, N. (2019). Physical properties and consumer acceptability of basic muffin made from pumpkin puree as butter replacer. *Food Research*, 840–845. https://doi.org/10.26656/fr.2017.3(6).090