JAP&T
TPA-Timisoara

Available online at https://www.journal-of-agroalimentary.ro/

Journal of Agroalimentary Processes and Technologies 2024, *30* (1), 58-65

Journal of Agroalimentary Processes and Technologies

Development of gluten-free cupcakes using cactus mucilage as a new natural hydrocolloid

Mohamed E. Salem*, Fatma M. El-Zayet, Ahmed M. Rayan* and Adel A. Shatta

Food Technology Department, Faculty of Agriculture, Suez Canal University, Ismailia 41522, Egypt

Abstract

There is a growing interest in manufacturing of gluten-free (GF) bakery goods due to the increased risk of chronic diseases such as gluten allergies and celiac disease. The study aimed to examine the effect of using cactus mucilage powder (CMP) as a new natural hydrocolloid on the physico-chemical properties, texture profile and sensory characteristics of GF cupcakes. Wheat flour was substituted with rice flour (RF) utilizing various concentration of xanthan gum (XG) and CMP. All tested physicochemical properties were enhanced with the addition of CMP. Moisture content was significantly higher ($p<0.05$) in both samples containing CMP and XG than control. All GF formulae containing CMP as a natural hydrocolloid received high acceptance in sensory scores compared to control. Texture profile analysis (TPA) results indicated that enhancement in firmness, cohesiveness, gumminess, chewiness, springiness and resilience in containing CMP cupcakes. Therefore, CMP could be considered interesting natural hydrocolloid for gluten-free cupcake production.

Keywords: cactus mucilage powder; celiac disease; xanthan gum; physicochemical properties; sensory characteristics; texture profile analysis (TPA).

1.Introduction

Enhancing the nutritional value of products that are consumed by a certain percentage of population represents the main strategy to meet consumers who are looking for better nutritional options and more health benefits [1, 2]. Due to the rising prevalence of gluten-related illness, there has been a global surge in the consumption of gluten-free products. According to Singh et al. [3], celiac disease (CD) is a genetic autoimmune condition that affects people worldwide. Gluten sensitivity negatively impacts CD patients' small intestines, leading to inflammation and impaired nutritional absorption from food [4]. For this reason, it's imperative that they follow a lifelong diet of gluten-free (GF) foods. However, the majority of celiac patients find gluten-free items to be unaffordable [5]. The growing number of individuals with CD or gluten intolerance has led to a surge in the market demand for gluten-free (GF) products, as well as an increase in efforts to enhance the quality of GF products by imitating wheat bakery products [6].

Cakes are among the most widely consumed bakery products worldwide, enjoyed by people of all walks of life. The most crucial ingredient in cake is wheat flour. Viscoelastic properties are provided by wheat gluten, which also determines the final structure of baked products. These days, it seems that people with celiac disease are searching for various gluten-free products that are also highly nutritious [7]. Producing gluten-free baked products is difficult from a technological and nutritional standpoint because the flour used to make GF bakery goods is of low quality and lacks fiber, nutrients, and vitamins. As a result, different types of additives and alternative flours (such as hydrocolloids, alternative protein sources, and so on) must be used in the recipes to create a network that is similar to gluten [8].

Rice flour has numerous distinctive qualities such as white color, easy digestion, and bland taste. Although rice flour has many benefits, forming batter or dough is extremely challenging due to the

* Corresponding author: Ahmed M. Rayan, E-mail: ammrayan@yahoo.com (https://orcid.org/0000-0003-3544-4675); Mohamed E. Salem, Email: m.salm68@yahoo.com

absence of gluten protein. The primary approach for creating leavened goods from gluten-free flours involves adding polymeric materials, which mimic the characteristics of gluten by creating a certain volume that is similar to wheat [9]. Since gluten plays little part in cake batter, the structure of cakes is often made up of gelatinized starch granules trapped in foam-forming egg white protein. The proteins that give cakes their strength and shape were present in both flour and eggs. Once the starch gelatinizes and its linear amylose gels, rice flour, rather than wheat flour, gives cakes structure. The egg's and cake flour's structural strengthening effects are counterbalanced by the sugar and fat ingredients' tenderizing effects [10].

Hydrocolloids are a crucial component in regulating the final bread goods' quality attributes. Hydrocolloids are commonly employed in gluten-free recipes because they imitate some of the rheological properties of gluten, promote dough qualities, postpone the retrogradation of starch, and improve the texture, appearance, and stability of bread [11]. Moreover, the hydrocolloids increased the starch aqueous system's ability to hold water. The eggless cake with gums' increased moisture content can be attributed to the hydrocolloids' capacity to hydrate at room temperature and their self-interactions, which prevent them from competing with starchy polysaccharides and gluten proteins for the water in the system [12]. According to Siminiuc and Ţurcanu [13], numerous flours, starches, and hydrocolloids have been studied to mimic the viscoelastic characteristics of gluten in wheat doughs. From the several studies were that among hydrocolloids, xanthan gum (XG) and cactus mucilage powder (CMP) showed the appropriate quality in bread manufacturing. XG is an extracellular heteropolysaccharide with a molecular weight around 1000 kDa secreted by the microorganism *Xanthomonas campestris* [14].

According to **CAPMS** (2022), the annual Egypt yield of cactus pear fruits to approximately 27796 tons produced from 2734 of fruitful cactus pear trees. Opuntia ficus-indica (*O. ficus-indica*), a genus of spineless cactus, has mucilage made up of heteropolysaccharide hydrocolloids with a variety of physicochemical characteristics., low-cost, safe great water retention capacity and biodegradable source [15]. *Opuntia ficus-indica* mucilage consists of a complex carbohydrate mixture with varying amounts of L-arabinose, D-galactose, L-rhamnose, and D-xylose. It also contains galacturonic acid, which has the potential to be used as an ingredient in food products because of its technological such as viscosity and nutritional benefits [16].

Xanthan gum and CMP are compatible with numerous food ingredients, including starch-improved dough rheology, baking qualities, texture, eating quality, and appearance of produced gluten-free bakery goods [17]. There are no studies on the impact of hydrocolloids on the qualities of gluten-free cupcakes. Furthermore, cupcakes are the predominant snack food in the Middle East, including Egypt. Therefore, the purpose of this study was to make GF cupcakes based on rice flour and assess the impact of varying XG and CMP concentrations on cupcake quality.

2.Materials and methods

Materials

Cactus stems (*O. ficus-indica)* were obtained from a local farm at El-Raed Village, Suez Governorate, Egypt. Ingredients used for GF cupcake processing including rice flour (Dobella), xanthan gum, sugar, salt, corn oil, baking powder, egg (fresh) and milk were procured from the local market in Ismailia Governorate, Egypt.

Cactus mucilage powder preparation

Cactus stems were washed to remove the gloquids then peeled, sliced and dried using hot-air oven (60°C/12 h). After being dried, the slices were ground into uniform granules using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany). The resulting fine powder was then sieved using a sieve with a particle size of 150 µm. The latter powder was heat-sealed, placed inside a high-density polyethylene bag, and kept in the freezer until use. The chemical composition of CMP and RF used in the preparation of GF cupcake is illustrated in Table 1.

Table 1. Chemical composition rice flour and Cactus mucilage powder (g 100 g^{-1} dry weight)

Raw materials	Moisture	Protein	Crude fat	Crude fiber	Ash	Total carbohydrates
CMP	11.8 ±0.45	6.72 ±0.55	0.5±0.06	7.5 ±0.76	20.2 ±1.20	65.26±1.01
RF	13.4 ±0.75	8.7 ±0.45	1.42 ±0.34	0.4 ±0.06	0.51 ±0.04	88.27±0.126

CMP: Cactus mucilage powder, RF: Rice flour

Blends preparation and experimental plan

The cupcakes were produced by the method described by Sung and Chai [18] with minor modifications. A lab dough mixer was used to prepare the dough. Using a flat beater, the corn oil (50 ml) and sugar powder (85 g) were combined in a mixer on high speed for 10 min until the mixture turns light. Eggs (50 g), salt and milk (100 ml) were added with continuous mixing. Rice flour (100 g), leavening agents (4 g) and vanilla (2.5 g) were put in the bowl of the dough mixer and blended for 10 min to obtain a cohesive dough. Rice flour batter gravity was adjusted to transfer to cups (B10 cm, 50 g). Baking was accomplished in an oven at 180ºC top and 150ºC bottom (Deck oven, Sam Mi Ind. Co., Seoul, Korea) for 15 -20 min. The cups was left to cool in the cup for 1 h. Five formulas were used in GF cupcakes production: **C** (control): 100% rice flour (RF), T1: 99% RF + 1% xanthan gum (XG), T2: 98% RF + 2% XG, T3, 99% RF + 1% cactus mucilage powder (CMP), T4: 98% RF + 2% CMP.

Methods of analysis

*Physicochemical properties.*The moisture, crude protein, crude fat, ash and crude fiber were determined according to **AOAC** [19]. Total carbohydrates were calculated by difference; while the values of crude protein, fat, and carbohydrate were multiplied by their corresponding physiological fuel values of 4, 9, and 4, respectively to calculate the gross energy (calorific values) in Kilocalories per a 100 g of sample (Kcal/100g) [20]. All measurements were carried out in triplicates.

The Minolta Chroma meter CR-400 (Minolta Camera Co., Ltd., Osaka, Japan) was used in the reflection mode to measure the color properties of GF cupcakes. Every sample was measured five times from ten distinct sites. *L** (L*=0 (black), L*=100 (white), *a** (-a*= greenness, +a*= redness), and *b** (-b*= blueness, + b*= yellowness) were the parameters that were identified.

Evaluation of cupcake quality

*Physical properties.*Volume (cm^3) and weight (g) of cupcake samples for each treatment were recorded. The method outlined in AACC [21] was used to calculate the specific volume (cm^3/gm) by dividing the volume by the weight.

Texture profile analysis (TPA)

A universal testing apparatus (Cometech, B type, Taiwan) was used to measure TPA. A cylindrical aluminum probe with a diameter of 40 mm was utilized. To penetrate 50% of the depth, perform a double compression test at a speed of 1 mm/s. Resilience, cohesiveness (Ratio), gumminess (N), chewiness (N), firmness (N), and springiness (mm) were used to measure the ability to recover from stress after it has occurred. However, the former refers to retarded recovery. The latter relates to instantaneous recovery (that is, recovery that occurs just after the first compression when the probe is raised). After the crust was removed, texture measurements were made on samples measuring 40 x 40 x 30 mm [22].

Sensory characteristics of cupcakes

The sensory qualities of cupcakes samples made from different blends were assessed for various sensory qualities via sixteen (16) semi-trained panelists from Food Technology Department, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. While the samples were still fresh, the tests were carried out. Before the evaluation process began, each panelist received a briefing. Crust color, crumb porosity, aroma, taste, texture, appearance, and acceptability (consumer preference) were among the sensory attributes that were assessed. Like extremely—9, like very much—8, like moderately—7, like slightly—6, neither like nor detest—5, dislike slightly—4, dislike moderately—3, dislike very much—2, dislike extremely— 1 were the order of the hedonic scale [23]. The panelists were all regular cupcake consumers, water at ambient temperature was available for mouth wash between each evaluation.

Statistical analyses

Analysis of variance was performed on the gathered data (ANOVA). Using the statistical package for the social sciences (SPSS) ver. 20.00 (SPSS Inc., Chicago, IL, USA), means were assessed using the Duncan's Multiple Range Test.

3.Results and discussion

Physicochemical properties

Chemical composition of GF cupcake the resultant produced with RF, XG and CMP is presented in Table 2. The data revealed that highest protein content was observed in sample C (100% RF) (9.93%) followed by sample T2 (98% RF + 2% XG)

(9.75%) than the rest of samples. There were no significant differences (*p*>0.05) in fat, ash, carbohydrates contents as well as caloric values between the investigated samples. Slight differences were noticed with regard to fiber content between the investigated samples where sample T1 (99% RF + 1% XG) recorded the highest value (0.59%) for fiber, while sample T3 (99% RF + 1% CMP) recorded the lowest value (0.46%). The caloric value ranged between 419.20 - 422.92 kcal/100g for the investigated samples. The obtained results are in consistent with the findings of Hassan *et al.* [24] who reported that cakes produced from rice flour contained 10.80% protein, 17.74% fat, 2.33% ash and 0.30% fiber and higher content of total carbohydrates 68.83%.

Color is one of the most crucial elements that directly influences a product's adoption by consumers. In order to grab consumers' attention, bakery products should receive extra attention [24]. Fig. 1 indicated that a high *L** value for sample C (100% RF), followed by sample T3 (99% RF + 1% CMP) which contained 1% CMP. Low *L** values were observed in samples containing 1% XG (T2) (98% RF + 2% XG) and 1% CMP (T3) (99% RF + 1% CMP).

Table 2. Chemical composition (g/100g, dry basis) and caloric value (Kcal/100g) of GF cupcake produced using RF, XG and CMP.

Cupcakes treatments	Protein	Fat	Fiber	Ash	Carbohydrates	Calories
C	9.93±0.03^{a}	21.81±0.13^{a}	0.50±0.03^{ab}	1.61±0.04^{a}	66.15±0.15^{a}	421.53±0.64^{a}
T1	9.84±0.02^{b}	21.70±0.03^{a}	0.59±0.02^{ab}	1.93±0.25^{a}	66.03±0.26^{a}	422.92±0.54^{a}
T2	9.75±0.04^{c}	21.69±0.02^{a}	0.48±0.05^{ab}	1.58±0.04^{a}	66.49±0.06^{a}	420.97±0.13^{a}
T3	9.90±0.07^{ab}	21.70±0.05^{a}	0.46±0.07^{b}	1.71±0.11^{a}	66.23±0.12^{a}	420.69±0.75^{a}
T4	9.89±0.06^{ab}	21.69±0.7^{a}	0.54±0.10^{a}	1.90±0.18^{a}	66.68±0.18^{a}	419.20±0.95^{a}

Each value is mean of 3 replicates. Means within a column marked with different letters are significantly different at (*p*<0.05). **C:** 100% RF, **T1**: 99% RF + 1% XG, **T2:** 98% RF + 2% XG, **T3**, 99% RF + 1% CMP, **T4**: 98% RF + 2% CMP

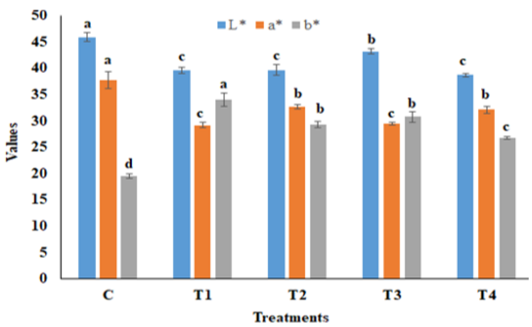

Figure 1. Color attributes of GF cupcakes produced from rice flour, Xanthan gum and Cactus Mucilage Powder. Each value is mean of 3 replicates. Means marked with different letters are significantly different at (*p*<0.05). C: 100% RF, T1: 99% RF + 1% XG, T2: 98% RF + 2% XG, T3, 99% RF + 1% CMP, T4: 98% RF + 2% CMP.

The higher *L** value could be attributed to the gums' ability to hold onto moisture during baking, which could lessen the degree of crust changes in baked goods [25].

Thus, the lightening of cake was resulted from changes in crust where uniform crust is more than the non-uniform one which could enhance *L** values Hesarinejad, [26]. Regarding the *a** values, sample C (100% RF) recorded the highest value (37.7) while T1(99% RF + 1% XG) sample recorded the lowest value (29.16). On the other hand, all samples including XG and CMP showed higher *b** value than the C (100% RF) sample.

Gluten Free Cupcake quality characteristics

Cakes with a spongy texture, low density, high volume, and light weight are considered to be of superior quality. Table 3 displays the GF cupcake's quality characteristics. An increase in the moisture content can enhance the overall quality of baked goods during storage, making it a crucial quality attribute [27]. Cupcake samples ranged in moisture content from 23.24 to 27.38%. Samples containing CMP and XG had considerably greater moisture concentrations than the control. The moisture contents rose as mucilage concentrations increased, yet the differences were statistically significant (p<0.05). These outcomes might be the result of an interaction between the flour and water caused by the hydrophilic nature of the added hydrocolloid.

More water is absorbed as a result of the hydrogen bonding interaction between the hydroxyl groups of the mucilage and water [28]. The type of hydrocolloid and how it interacts with the other compounds in the formulation determine this aspect of hydrocolloids [29].

It was found that the highest weight (44.82 g) was recorded for C (100% RF) sample while the lowest weight of T2 (98% RF + 2% XG) sample. The highest value for volume was recorded for T4 (98% RF + 2% CMP) (43.33 cm^3) and the lowest one of for T2 (29.33 cm^3) (98% RF + 2% XG). The highest value of specific volume in the sample was (1.47) for T2 (98% RF + 2% XG) and the lowest specific volume of T4 (98% RF + 2% CMP) (1.29). The viscosity of the batter was enhanced by soluble fiber, which also might have facilitate the formation of starch-lipid or starch-protein complexes, which stabilize the cake batter during baking [30]. According to **Marston et al.** [31], the less extensive swelling of the starch granule in rice flour resulted in a weaker gel system than that of xanthan gum addition or flaxseed flour replacement. These benefits of adding xanthan gum or substituting flaxseed flour appear to hold true in the experiment. As the specific gravity dropped and the batter viscosity grew, more air bubbles became trapped in the batter system. Furthermore, the stronger batter system helps in preventing gas cell coalescence and collapsing after cooling.

Table 3. Moisture, weight, volume and specific volume of GF cupcakes produced from RF, XG and CMP.

Cupcakes Treatment	Moisture (%)	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)
C	24.86 ± 1.08^{bc}	44.82 ± 0.40^{a}	31.66 ± 2.88^{ab}	1.41 ± 0.11^{a}
T1	23.24 ± 0.97^{c}	43.55 ± 0.26^{b}	33.00 ± 2.64^{ab}	1.31 ± 0.09^{a}
T2	27.38 ± 0.37^{a}	43.20 ± 0.21^{b}	29.33 ± 1.15^{b}	1.47 ± 0.37^{a}
T3	26.48 ± 1.68^{ab}	44.77 ± 0.03^{a}	30.66 ± 2.08^{ab}	1.46 ± 0.09^{a}
T4	26.17 ± 1.69^{ab}	44.35 ± 0.28^{a}	34.33 ± 1.52^{a}	1.29 ± 0.05^{a}

Each value is mean of 3 replicates. Means within a column marked with different letters are significantly different at ($p<0.05$). **C:** 100% RF, **T1**: 99% RF + 1% XG, **T2:** 98% RF + 2% XG, **T3**, 99% RF + 1% CMP, **T4**: 98% RF + 2% CMP.

Table 4. Texture profile analyses of GF cupcakes produced from RF, XG and CMP.

Cupcakes Treatment	Firmness (N)	Cohesiveness (N)	Gumminess (N)	Chewiness (N)	Springiness (mm)	Resilience (mm)
C	3.87^{e}	0.36^{c}	1.44^{e}	0.64^{c}	0.45^{c}	0.29^{b}
T1	5.00^{d}	0.54^{a}	2.81^{d}	2.49^{b}	0.93^{a}	0.35^{a}
T2	9.66^{b}	0.49^{ab}	4.69^{b}	2.74^{a}	0.58^{b}	0.29^{ab}
T3	10.4^{a}	0.46^{b}	4.90^{a}	2.73^{a}	0.56^{b}	0.35^{a}
T4	8.34^{c}	0.50^{ab}	4.21^{c}	2.45^{b}	0.58^{b}	0.31^{ab}

Each value is mean of 3 replicates. Means within a column marked with different letters are significantly different at ($p<0.05$). **C:** 100% RF, **T1**: 99% RF + 1% XG, **T2:** 98% RF + 2% XG, **T3**, 99% RF + 1% CMP, **T4**: 98% RF + 2% CMP.

Cohesiveness measures the internal resistance of food structure [33]. Like firmness, fresh cupcake cohesiveness depended on the level of CMP or XG addition. The degree of addition of 1% XG (T1, 0.54) produced the highest cohesiveness value while the lowest value of cohesiveness was recorded for sample C (100% RF). Chewiness represents one of texture characteristic that is connected with sensory studies using trained panels. Since gumminess and chewiness are factors that depend on firmness, their values in both fresh and stored cupcakes follow a similar trend to those of firmness.

The highest value of chewiness and gumminess were recorded at the level of addition of 1% CMP (T1), 2 % XG (T2). Resilience and springiness are measures of the ability of a sponge to recover after compression [34]. In the fresh cupcake, sample C (100% RF) and T2 recorded the lowest value of resilience being 0.29 mm whereas T1 and T3 recorded the highest value at addition level of 1% XG and 1% CMP (0.35mm). The highest value of springiness was recorded at addition level 1% XG (T1, 0.93 mm). These results are in consistent with those obtained by **Amer** [35].

Sensory evaluation

Sensory qualities are crucial in assessing the acceptability of processed food products [20]. Thus, the sensory evaluation of cupcake samples was assessed in terms of crust color, texture, crumb porosity, aroma, taste, appearance, and overall acceptability (Fig. 2). When 1% and 2% CMP were added, the greatest approval score was achieved. The most acceptable sample was T4 (98% RF + 2% CMP) with overall acceptability score of 8.2 which got the highest scores in all evaluated characteristics, followed by sample T3 (99% RF + 1% CMP). The lowest sample in sensory acceptance was sample C (100% RF) (6.9). High concentration of CMP led to a highest score of porosity, appearance, flavor, hardness and overall acceptability. Gums improved acceptance in terms of flavor, texture, softness, and moisture retention [35]. Previous study has documented the ameliorative impact of varying gum additions on cake texture [35].

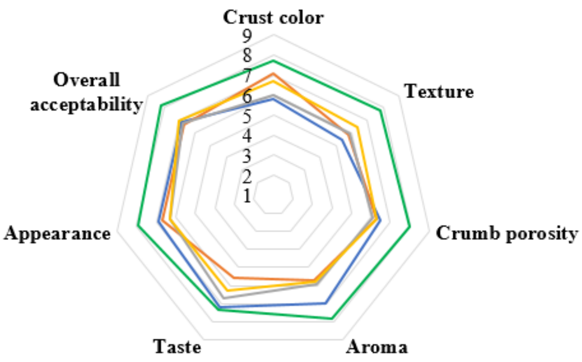

Figure 2. Sensory evaluation scores of GF cupcakes produced from RF, XG and CMP. C: 100% RF, T1: 99% RF + 1% XG, T2: 98% RF + 2% XG, T3, 99% RF + 1% CMP, T4: 98% RF + 2% CMP.

Conclusion

This study investigated the possibility of utilizing the mucilage from *O. ficus-indica* as natural hydrocolloid in the manufacturing of gluten-free cupcake. The cupcake containing CMP exhibited similar properties to samples contained xanthan gum (as commercial hydrocolloids) with an additional improvement in, physicochemical properties and texture profile analysis, as well as the sensory acceptability score. When 1% and 2% CMP were added into cupcake formulae, the greatest approval score was achieved. Finally, the CM obtained from *O. ficus-indica* cactus met the specifications needed to create gluten-free cupcakes and may also be used as prospective functional technology ingredients in food applications.

Compliance with Ethics Requirements. The authors declare that they comply with the Ethics requirements of the journal. The authors declare that they have no conflicts of interest and that all procedures involving human or animal subjects (if any) comply with specific regulations and standards.

Author contributions

Mohamed Salem: Conceptualization, methodology, investigation, visualization, writing-original draft; **Fatma El-Zayet**: Resources, visualization; **Ahmed Rayan**: Data curation, investigation, resources, validation, writing-review & Editing; **Adel Shatta**: Conceptualization, supervision, writing-review & Editing

Funding Not applicable.

Data availability Data will be made available on request.

Code availability Not applicable.

Confect of interest The authors declare that they have no conflict of interests.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Applicable.

References

1. Boff, J.M Strasburg, VJ Ferrari, GT.de Oliveira Schmidt, H Manfroi, V de Oliveira, VR Chemical (2022) Technological, and Sensory Quality of Pasta and Bakery Products Made with the Addition of Grape Pomace Flour. Foods. 11, 3812. https://doi.org/10.3390/11233812
2. Salem M E, El-Zayet F M, Rayan A M, Shatta A A (2019) Physicochemical properties and acceptability of gluten-free biscuits as affected by some cereals and tubers type. Journal of Food Sciences Suez Canal University 6, 1–12.
3. Singh P, Arora A, Strand T A, Leffler k D A, Catassi C, Green P H, Kelly C P, Vineet Ahuja A, a Makharia, G K (2018) Global prevalence of celiac disease: Systematic review and meta-analysis. Clin. Gastroenterol. Hepatol., 16(6), 823-836. https://doi.org/10.1016/j.cgh.2017.06.037
4. Biagi, F, Raiteri, A, Schiepatti A., Klersy, C, and Corazza, G R. (2018) The relationship between child mortality rates and prevalence of celiac disease. J. Pediatr. Gastroenterol. Nutr. 66(2), 289–294. https://doi: 10.1097/MPG.0000000000001696
5. Lindfors K., Ciacci C, Kurppa K, Lundin, K E A, Makharia, G K Mearin, LM Murray, J A Verdu, E F, Kaukinen, K (2019) Coeliac disease. Primer 5–18. https://doi.org/10.1038/s41572-018-0054-z

6. Nicolae A, Radu G L, Belc N (2016) Effect of sodium carboxymethyl cellulose on gluten-free dough rheology. J. Food Eng.,168, 16–19. https://doi.org/10.1016/j.jfoodeng.2015.07.006
7. El Tanahy, H. H, Sharoba, A.M Ghazal, G.A., Abd Elmola, E.M, and Zamzam, E.H (2021). Improve the Nutritive Value of Produced Cake by Replacement Wheat Flour with Pearl Millet Flour. International Conference on Biotechnology Applications in Agriculture (ICBAA), Benha University, 8 April 2021, Egypt (Conference Online)
8. Marnilo S M, Yarmand M S, Salami M, Aliyari M A, Emam-Djomeh, Z, Mostafav Y S (2023). Development of Gluten-Free Cake for Improving Textural and Sensory Characteristics with Chia Flour. Journal of Food Processing and Preservation Volume, 4923259, 12 https://doi.org/10.1155/2023/4923259.
9. Hamada S, Suzuki K, Aoki N, and Suzuki Y (2013) Improvements in the qualities of gluten-free bread after using a protease obtained from *Aspergillus oryzae*. Journal of Cereal Science 57 (1), 91-97. https://doi.org/10.1016/j.jcs.2012.10.008.
10. Jan N, Naik H R, Gani G, Bashir O, Amin T, Wani S M, Sofi S A (2022) Influence of replacement of wheat flour by rice flour on rheo-structural changes, in vitro starch digestibility and consumer acceptability of low-gluten pretzels. Food Production, Processing and Nutrition (2022) 4:9. https://doi.org/10.1186/s43014-022-00088-y
11. Culetu A, Duta DE, Papageorgiou M, Varzakas T (2021) The role of hydrocolloids in Gluten-Free Bread and Pasta; Rheology, Characteristics, Staling and Glycemic Index. Foods, 10, 3121. https://doi.org/10.3390/ foods10123121
12. Wang P, Tao H, Jin Z, Xu X (2016) Impact of water extractable arabinoxylan from rye bran on the frozen steamed bread dough quality. *Food Chem.*, *200*, 117–124. https://doi.org/10.1016/j.foodchem.2016.01.027
13. Siminiuc R, Țurcanu D (2023) Technological approaches applied in the design of gluten-free bakery products. Czech J. Food Sci. 2023;41(3):155-172. https://doi.org/10.17221/180/2022-CJFS.
14. Horstmann SW, Axel C, Arendt EK (2018) Water absorption as a prediction tool for the application of hydrocolloids in potato starch-based bread. Food Hydrocoll. 81:129–138. https://doi.org/10.1016/j.foodh yd.2018.02.045
15. Contreras-Padilha M, Rodríguez-García, M.E Gutiérrez- Cortez, E Valderrama-Bravo, M C Rojas-Molina, J I Rivera-Munoz EM (2016) Physicochemical and rheological characterization of *Opuntia fícus* mucilage at three diferente maturity stages of cladode. Eur Polym J03.024. https://doi.org/10.1016/j.eurpo lymj.2016.03.024
16. Quintero-García, M , E Gutiérrez-Cortez, Moustapha B , Alejandra R , M ,María A. C , Alicia D,R and Isela Rojas-Molina (2021) Comparative Analysis of the Chemical Composition and Physicochemical Properties of the Mucilage Extracted from Fresh and Dehydrated Opuntia ficus indica Cladodes. Foods 2021, 10, 2137. https://doi.org/10.3390/foods10092137
17. Mousavi S F, Razavi S M, Koocheki A (2019). Marshmallow (*Althaea officinalis*) Flower Gum. Emerging Natural Hydrocolloids: Rheology and Functions, 397-423. https://doi: 10.1002/9781119418511.ch16
18. Sung W C, Chai P (2017) Effect of Flaxseed Flour and Xanthan Gum on Gluten-Free Cake Properties. J. Food Nutr. Res., 5(10), 717-728.
19. AOAC (2016) “Official Methods of Analysis” Association Official Analytical Chemists of the 20 th Ed. International, Gaithersburg, MD, USA.
20. Bello FA., O J Ntukidem and B S Oladeji (2018) Assessment of chemical compositions, physical and sensory properties of biscuits produced from yellow yam, unripe plantain and pumpkin seed flour blends. Int. J. Food Sci. Nutr. Eng.8(5): 119-126. https://doi:10.5923/j.food.20180805.02
21. AACC (2000) Approved method of analysis (10th ed.). St. Paul, MN: USA: American Association of Cereal Chemists.
22. Bourne, M C (2002) Food texture and viscosity. Concept and measurement, 2nd Ed. Academic Press. London, pp. 427.
23. Mishra A M, Devi P Jha (2015) Development of gluten free biscuits utilizing fruits and starchy vegetable powders. J. Food Sci. Technol 52(7): 4423–4431. https://doi: 10.1007/s13197-014-1521-5
24. Hassan E. M., Hany A. Fahmy, Shimaa Magdy and Magda I. Hassan (2020). Physicochemical and sensorial characterization of gluten-free cupcakes. Egyptian J. of Nutrition Vol. XXXV No. 1 (2020) 33
25. Alamri, M.S., Mohamed,A.A., Hussain, S., Ibraheem, M.A.,Qasem, A.A.A., Shamlan, G.;Hakeem, M.J., Ababtain, I.A. (2022) Functionality of Cordia and Ziziphus Gums with Respect to the Dough Properties and Baking Performance of Stored Pan Bread and Sponge Cakes . Foods 2022, 11, 460. https://doi.org/10.3390/foods11030460
26. Hesarinejad M A, Siyar Z, Rezaiyan Attar F (2019) Investigating the effect of wheat flour enrichment with Phaseolus vulgaris flour on the physical, sensory and shelf-life characteristics of sponge cake. FSCT 16 (86), 213-222.
27. Dadkhah A, Hashemiravan M, Seyedain-Ardebili, M (2012) Effect of shortening replacement with nutrim oat bran on chemical and physical properties of shortened cakes. Annals of Biological Research 3(6), 2682-2687.

28. Song K Y, Joung K Y, Shin S Y, Kim Y S (2017) Effects of Basil (*Ocimum basilicum)* sponge cake. Food Sci. Technol., 16(86) 213– 222.
29. Mousavi, S. F., Razavi, S. M., & Koocheki, A. (2019). Marshmallow (Althaea officinalis) Flower Gum. Emerging Natural Hydrocolloids: Rheology and Functions, 397-423.
30. Anwar DA, Shehtta H.A, Eid H.R, and Soliman, SA (2020) Development of eggless cake physical, nutritional and sensory attributes for vegetarian by using whole meal chia (*Salvia hispanica* L.) flour. Middle East Journal of Applied Sciences,10: 313-329.doi: 10.36632/2020.10.2.30
31. Marston K, Khouryieh H, Aramouni F(2016) Effect of heat treatment of sorghum flour on the functional properties of gluten-free bread and cake. LWT-Food Sci Technol *65*: 637-644. https://doi.org/10.1016/j.lwt.2015.08.063
32. Alemu, T (2023) Texture Profile and Design of Food Product. J Agri Horti Res. 6(2), 272-281.
33. Murugkar D A, Zanwar A A, Shrivastava A (2021) Effect of nano-encapsulation of flaxseed oil on the stability, characterization and incorporation on the quality of eggless cake. Food Research 1(2) 100025. https://doi.org/10.1016/j.afres.2021.100025.
34. Marzec A, Kowalska J, Domian E, Galus S, Ciurzy ´nska, A, Kowalska H (2021) Characteristics of Dough Rheology and the Structural, Mechanical, and Sensory Properties of Sponge Cakes with Sweeteners. Molecules 2021, 26, 6638. https:// doi.org/10.3390/molecules26216638
35. Amer T. A. M.. (2019). Influence of Carboxy Methyl Cellulose and Xanthan Gum on the quality characteristics of Gluten Free Cake. Middle East J. Appl. Sci., 9(3): 825-838, 2019
36. Farimani TY, Hesarinejad M A, Tat M (2020) A new study on the quality, physical and sensory characteristics of cupcakes with *Althaea officinalis* mucilage. Iranian Food Sci. Technol. Res. J., 16 (3), Aug. Sep. 2020, p. 25-35