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Physicochemical and Sensory Properties of Gluten-free Cupcakes Produced with Pearl Millet Flour and Cactus Mucilage Powder as a New Natural Hydrocolloid

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Abstract: This study aimed to produce functional gluten-free cupcakes from pearl millet flour (PMF), rice flour (RF) and cactus mucilage powder (CMP) as a natural hydrocolloid. Rice flour was mixed with pearl millet flour at percentage of 25%, 50%, 75% and 100% (as control). Physicochemical, sensory evaluation and texture profile (TPA) characteristics of gluten-free cupcakes were performed. Results revealed that free-gluten cupcakes produced with pearl millet flour had a higher content of protein, ash, fat, and fiber than control (100% RF). Additionally, the sensory characteristics of cupcakes containing 50 % RF+ 50% PMF + 2% CMP were the most acceptable formulae among the investigated treatments. TPA results showed that the substitution with PMF decreased firmness, cohesiveness, gumminess, chewiness, springiness, and resilience of all resultant cupcake samples than control. Therefore, we recommend using pearl millet flour and cactus mucilage as a functional ingredient in the manufacturing of gluten-free bakery products.

Keywords: pearl millet flour; gluten-free cupcake; natural hydrocolloids; physicochemical properties; sensory evaluation.

1. Introduction

Bakery products are readily available, palatable, and have high nutritional value, as they are popular worldwide. However, the growing population with dietary limitations resulting from non-celiac gluten sensitivity and celiac disease as well as gluten related disorders (GRD) is driving the demand for gluten-free (GF) products because they believed that will improve their overall health and well-being [1]. Worldwide, the typical prevalence of celiac disease in the general population is between 1 and 2% [2]. Adhering to a strict gluten-free diet for the entirety of a patient's life is the only effective treatment for celiac disease [3 and 4]. The GF diets had an issue with nutrient deficits because of the low intake of protein, dietary fiber, vitamins, and minerals [5]. A newly created functional food's commercial viability is highly dependent on a number of elements in addition to its health benefits as

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well as the standard indicators of quality (taste, affordability, and ease of use) [6]. However, a number of challenges with cereal food's sensory qualities such as taste, color, and texture during processing and after supplementation with natural sources rich in bioactive compounds and dietary fiber can be linked to the limited application of some processing technologies [7].

Cakes are one of the most popular bakery products because they are intriguing products that are frequently used on pleasant occasions [8]. Cake, by definition, is a semi-dry foamed baked item where air bubbles become caught in the starch and protein matrix contained in the batter's aqueous phase [9]. Low density, high volume, spongy structure, and light weight are characteristics of high-quality cakes. The porous and soft structure of cake is a result of carbon dioxide production, protein denaturation, and starch gelatinization [10]. Cakes fall within the category of baked goods with an intermediate moisture level, often ranging from 22% to 28% [11]. Traditional cupcakes are tasty with a high nutritional value that are manufactured using low-gluten flour, which has less than 9% gluten protein. In order to achieve the desired viscoelasticity of the flour batter, a cohesive protein network must form. To capture the most gas released during baking and provide the optimal texture expansion, the acceptable network structure in the base dough is essential [12]. Since gluten is the primary structural protein that gives dough its viscoelasticity and contributes to the sensory properties of many baked goods, substituting other ingredients for gluten typically results in a decrease in both technological and sensory qualities (low volume, poor texture, color, unsatisfactory taste, crumb structure, etc.) [4]. Because GF foods do not have the viscoelastic property that gluten imparts, they have presented a difficulty to product developers. To fulfill the increasing demand for high-quality GF goods, numerous approaches have been investigated to enhance the organoleptic features, functionality, and nutritional profiles. The introduction of functional ingredients (hydrocolloids, enzymes, starch, protein) and technological advancements (instant controlled pressure drop, extrusion, hot air toasting, and so on) are potential ways to improve the physical and organoleptic features of GF products [13]. Again, nutritionally speaking, making gluten-free baked goods is a challenge since baking GF flour lacks vitamins, minerals, and fiber [4].

Millet is one of the most significant drought-resistant crops, widely cultivated in the semi-arid tropical regions of Asia and Africa, providing a significant portion of the population's protein and carbohydrate needs [14]. Additionally, food scientists, technologists, and nutritionists are becoming more interested in millet grain due to its significant contribution to national food security and possible health advantages [7 and 15]. After wheat, rice, barley, corn, rye, oats, and corn, pearl millet is regarded as the eighth most productive crop in the world [16]. Pearl millet is also the descent source of protein and carbohydrates and a good source of fibers, vitamins and minerals [17]. Because pearl millet is regarded as a gluten-free grain and it is a desired ingredient for making gluten-free products [18].

Rice flour has several important characteristics, including being natural, colorless, and bland, making it one of the best cereal flours for making gluten-free goods. It also contains hypoallergenic proteins, low fat and sodium levels, and high carbohydrate content that is easily digested [1 and 19].

Hydrocolloids play a significant role in regulating the bakery product's quality attributes. They are commonly employed in gluten-free recipes because it could mimic some of the rheological characteristics of gluten, enhance dough qualities, postpone the retrogradation of starch, improve the texture, appearance, and stability of the product [20]. A novel low-cost hydrocolloid called cactus pear mucilage is used to give functional food products their body, texture, and nutrients [21]. *Opuntia ficus-indica* mucilage consists of a complex carbohydrate mixture with varying levels 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 and nutritional benefits [22].

In light of the aforementioned, as well as the rising demand for high-quality gluten-free products and the discovery of novel components that may aid in enhancing the composition and end qualities of gluten-free cakes, the aim of this study was to produce gluten-free cupcakes by using rice and PMF at different concentrations with 2% CMP as a natural hydrocolloid. In addition, the resultant gluten-free cupcakes were also evaluated for physico-chemical, sensory, and texture attributes characteristics.

2. Materials and methods

2.1. Materials

Pearl millet (*Pennisetum americanum L*., cv. Shandawel-1) was procured from Crop Research Institute, Agricultural Research Center, Giza, Egypt. Cactus stems were obtained from a local farm at El-Raed Village, Suez Governorate, Egypt. Ingredients used for GF cupcake production including rice flour (Dobella), xanthan gum, sugar, salt, corn oil, baking powder, egg (fresh) and milk were purchased from a local market in Ismailia Governorate, Egypt.

2.1.1 Preparation of Pearl millet grain flour

The grains of pearl millet were sifted to remove any debris and broken grains. The grains were ground into granules using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany) and sieved using a 150 μm screen [15]. After being heat-sealed and placed in high-density polyethylene bags, the flour was kept in a freezer at -18°C until used.

2.1.2. Cactus mucilage powder preparation

Cactus stems were washed to remove the glochids then peeled, sliced and dried in hot-air oven (60°C/12 h). The dried slices were ground into uniform granules using a laboratory mill (Brabender Automat Mill Quandrumat Senior, Germany), and the fine flour was obtained by sieving them through a screen with a pore size of 150 μm [23]. Once the flour was obtained, it was sealed with heat and placed in high-density polyethylene bags, which were kept in the freezer till needed.

2.1.3. Cupcake preparation and experimental plan of cupcake production

Cupcake samples were produced by the method described by *Kim & Shin* and *Sung & Pei-Shan* [24 and 25] with minor modifications. Using a lab dough mixer, the dough was prepared. 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, or until the mixture turned 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 get a cohesive dough. The rice flour batter's gravity was adjusted before it was transferred to cups (B10 cm, 50 g). For 15–20 min, baking was done in a Deck oven (Sam Mi Ind. Co., Seoul, Korea) with a maximum temperature of 180°C and a bottom temperature of 150°C. After that, it was let for 1 h to cool in the cup.

Table (1): Formulation of rice flour, Pearl millet flour and cactus mucilage powder blends (%) for GF cupcakes production.

Treatments	RF%	PMF%	CMP%
C (Control)	100	-	2
T1	75	25	2
T2	50	50	2
T3	25	75	2
T4	-	100	2

RF: Rice flour, PMF: Pearl millet flour, CMP: Cactus mucilage powder.

2.2. Methods of analysis

2.2.1. Physico-chemical properties

The following parameters: moisture, protein, fat, ash, and fiber were determined using [26]. Gross energy (Kcal/100g) was calculated by multiplying the values of protein, fat, and carbohydrate by the corresponding physiological fuel values of 4, 9, and 4, respectively [27]. Total carbohydrates were calculated by difference. Every analysis was carried out in triplicates.

The color reader CR-400 (Minolta Camera Co., Ltd., Osaka, Japan) was used in the reflection mode to measure the color attributes of GF cupcakes. Every sample was measured five times from ten distinct sites. L^* (0, black); 100, white), a^* ($-a^*$= greenness, $+a^*$= redness), and b^* ($-b^*$= blueness, $+b^*$= yellowness) were the parameters that were identified. Chroma (C^*) is expressed as the intensity of the color. The total color change (ΔE) was calculated by using the following equation [28] where L_0, a_0 and b_0 are the control values for the control sample:

$$\Delta E = [(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2]^{0.5}$$

2.2.2. Evaluation of cupcake quality

2.2.2.1. Physical properties

For each treatment, the weight (g) and volume (cm^3) of cupcake samples were recorded. The method outlined in [26] was applied to divide the volume by weight in order to calculate the specific volume (cm^3/gm).

2.2.2.2. 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 referred to retard recovery. The latter related to instantaneous recovery (that is, recovery that occurred 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 [29].

2.2.2.3. Sensory evaluation of the resultant cupcakes

The cupcakes sensory qualities were assessed via sixteen (16) semi-trained panelists from Food Tech. Dep., Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The samples were evaluated in its fresh form. 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. The panelists were all regular cupcake consumers, water at ambient temperature was available for mouth wash between each evaluation. A 9-hedonic scale was used which expressed as 9= like extremely, to reach 1 dislike extremely [30].

2.3. Statistical analysis

Analysis of variance was performed on the gathered data (ANOVA). The Statistical Package of the Social Sciences (SPSS) ver. 20.00 (SPSS Inc., Chicago, IL, USA) was used to process the data using the Duncan's Multiple Range Test.

3. 3. Results and discussion

3.1. Physicochemical properties

Proximate composition of the resultant GF cupcakes is presented in Table 2. For protein content, significant ($p < 0.05$) differences between the samples were increased with the increase the substitution of PMR flour. The highest protein content was observed in sample T4 (100% PMF) (14.97%) followed by T3 (13.9%), T2 (12.94%) and T1 (11.85%) compared to control (100%RF) (10.53%). This may be attributed to the high protein content of PMF. Also, sample T4 gave the highest fat content (21.11%) while the lowest was recorded for control (20.23%). Sample T4 recorded the highest value for fiber 2.45% and control (100% RF) recorded the lowest value of 0.63%. There were no significant ($p > 0.05$) differences in the ash content between investigated the samples, and which ranged between (1.3% -1.77%). Sample C recorded the highest value for carbohydrates (67.30%) and the sample T4 had the lowest samples in its content of carbohydrates (59.68%). The caloric value ranged between 414.01-415.58 kcal/100g for the investigated samples.

Table (2): Proximate composition (g/100g, dry basis) and calories (Kcal/100g) of the resultant gluten-free cupcakes

Cupcakes treatments	Protein	Fat	Fiber	Ash	Carbohydrates	Calories
C	10.53±0.35^{e}	20.23±0.44^{ab}	0.63±0.25^{e}	1.30±0.30^{a}	67.30±1.18^{a}	514.58^{a}
T1	11.85±0.17^{d}	20.50±0.50^{ab}	1.07±0.02^{ab}	1.41±0.30^{a}	65.16±0.90^{b}	415.53^{a}
T2	12.94±0.25^{c}	20.60±0.32^{ab}	1.56±0.20^{c}	1.57±0.26^{a}	63.32±0.53^{c}	414.17^{a}
T3	13.91±0.27^{b}	20.82±0.17^{ab}	1.97±0.21^{b}	1.68±0.20^{a}	61.61±0.86^{d}	414.02^{a}
T4	14.97±0.21^{a}	21.12±0.45^{a}	2.45±0.20^{a}	1.77±0.21^{a}	59.68±0.65^{e}	414.01^{a}

Each value is mean of triplicate. Means within a column marked with different superscript letters are significantly different at ($p<0.05$). RF: Rice flour, PMF: Pearl millet flour, CMP: Cactus mucilage powder. C (control): 100% RF + 2% CMP, T1: 75% RF + 25% PMF + 2% CMP, T2: 50% RF + 50% PMF + 2% CMP, T3: 25% RF + 75% PMF + 2% CMP, T4: 100 % PMF + 2% CMP.

The above mentioned, results were consistent with those obtained from the study conducted by *Hassan et al.* [15] who reported that cakes produced from rice flour contained 10.80% protein, 17.74% fat, 2.33% ash and 0.30% fiber and high percentage of total carbohydrates 68.83% and cakes made from pearl millet flour contained 14.87% protein, 20.52% fat, 3.30% ash and 1.35% fiber and high concentration of total carbohydrates 59.96%.

From Table 2, it is clear that PMF is a good source of protein and fat which increases the nutritive value of cupcake.

Color is one of the most crucial elements that directly influenced a product's adoption by consumers. In order to grab consumers' attention, bakery products should receive extra attention [31]. Figure 1. indicated that a highest L^* value for sample C (100% RF), while the lowest in T4 (100% PMF). It was observed that L^* value was decreased by the increase in the level of PMF in the formula.

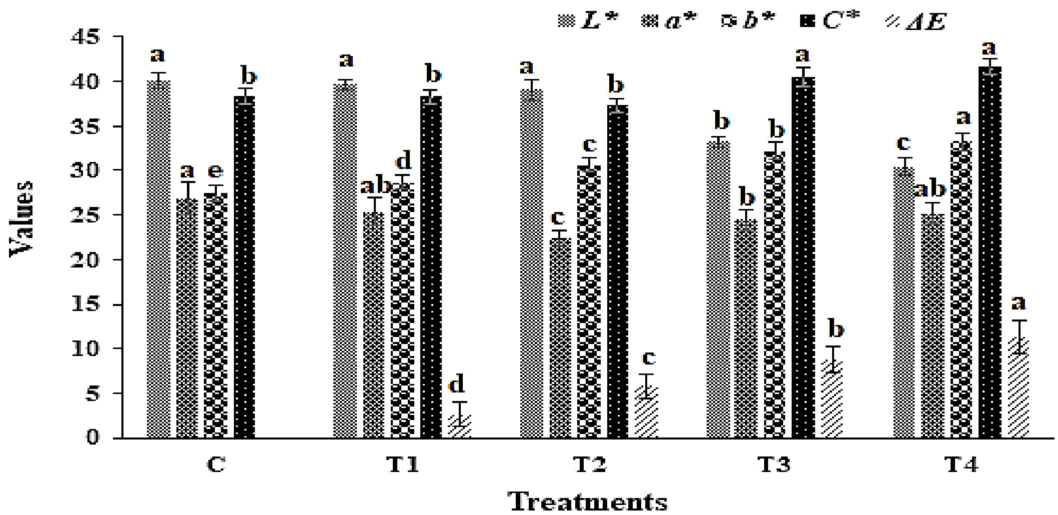

Fig. 1. Color attributes of GF cupcakes produced by rice flour, pearl millet flour and cactus mucilage powder. C (control): 100% RF + 2% CMP, T1: 75% RF + 25% PMF + 2% CMP, T2: 50% RF + 50% PMF + 2% CMP, T3: 25% RF + 75% PMF + 2% CMP, T4: 100 % PMF + 2% CMP. Each value is mean of six replicates. Mean values in the same column followed by different superscript lower-case letters are significantly different at ($p < 0.05$).

These findings concurred with those of *Mitharwa and Komal* [32], who discovered that the color of muffin crust darkened when the substitution amount of finger millet flour increased in relation to germinated black soybean flour + kenaf leaf powder. *Hassan et al.* [15] reported that cakes produced from 100% and 67% pearl millet flour and (made from 67g Millet +33g Rice starch) had the lowest *L** values, indicating significant increase in grayish color (low light). This might be attributed to the intense color of pearl millet added. Sample C recorded the highest value of *a** (26.9) and sample T3 recorded the lowest value (22.36). Sample T4 recorded the highest value for *b** (33.22) and sample control (100%RF) recorded the lowest value (27.44). In addition, chroma (*C** values) and *ΔE* were significantly ($p < 0.05$) increased by increasing the percentage of millet flour. Based on the findings of [33], pearl millet considerably reduced the *L** values, which turned from white to gray, the *a*-values, which turned from green to red, and the *b*-values, which turned from blue to yellow. According to *Mamat et al.* [34], the color of muffin crumbs is determined by the color of the components and is not influenced by the Maillard or caramelization reaction because the temperature in the crumb portion is lower than the crusts.

3.2. Physical parameters

Quality characteristics of GF cupcake are shown in Table 4. Significant differences ($p < 0.05$) were observed between the samples. The highest moisture content (23.86%) was observed in sample C (100% RF). A decrease in moisture was noticed with an increase in the content of pearl millet flour in samples. Sample T4 (100% PMF) recorded the lowest moisture content of (21.46%). *Khorasani et al.* [35] reported that the samples containing the higher amount of millet flour had the lowest moisture content. The authors attributed that to the high fiber content in millet flour. Our results are consistent with those reported by *Hassan et al.* and *El Tanahy et al.* [15 and 9].

It was found that the highest weight (45.30 g) was recorded for T2 sample while the lowest one was recorded for T4 sample (43.39 g). The highest value for volume of cupcake was recorded for T1 (34.33), T2 (43.33) and the lowest value was recorded for C (30.00). The highest value of specific volume was counted for sample C (1.49) and the lowest ones was recorded for T2 (1.31). The results obtained are consistent with the results by *Hassan et al.* [15]. According to *Agrahar-Murugkar et al.* [10], the distinct foaming, leavening, and heat coagulation characteristics of egg proteins as well as the evaporation of water during baking may be responsible for the larger specific volume of cakes. As a result, samples containing rice starch, which is crucial to the gelatinization process that produces high volume, may be responsible for the increases in specific volumes.

Table (4): Moisture, weight, volume and specific volume of gluten-free from rice flour, pearl millet flour and cactus mucilage powder.

Cupcakes treatments	Moisture %	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)
C	23.86±1.08^{a}	44.86±0.37^{a}	30.00±1.52^{b}	1.49±0.07^{a}
T1	22.71±0.03^{b}	44.80±0.60^{a}	34.33±0.57^{a}	1.33±0.02^{b}
T2	22.19±0.35^{bc}	45.30±0.15^{a}	43.33±0.57^{a}	1.31±0.02^{b}
T3	21.89±0.06^{bc}	43.61±0.98^{b}	30.33±1.52^{b}	1.43±0.04^{a}
T4	21.40±0.11^{c}	43.39±0.56^{b}	30.33±1.15^{b}	1.43±0.03^{a}

Each value is mean of triplicate. Means within a column marked with different letters are significantly different at ($p<0.05$). RF: Rice flour, PMF: Pearl millet flour, CMP: Cactus mucilage powder. C (control): 100% RF + 2% CMP, T1: 75% RF + 25% PMF + 2% CMP, T2: 50% RF + 50% PMF + 2% CMP, T3: 25% RF + 75% PMF + 2% CMP, T4: 100 % PMF + 2% CMP.

3.3. Texture profile characteristic (TPA) of the resultant cupcakes

Table 5 showed that a significant decrease in the firmness values with the increase in millet flour. Sample control (100%RF) recorded the highest value of firmness (8.12 N) while T2 recorded the lowest value (5.01N). The results are consistent with *Nada et al.* [36]. The internal resistance of the food structure is measured by cohesiveness [37]. Fresh cupcake cohesiveness depended on the level of PMF or CMP addition where non-significant increases ($p \geq 0.05$) were observed the values. The highest cohesiveness value was recorded at the sample T4 (0.69 N) while the lowest cohesiveness value was recorded for sample C (0.51 N). Gumminess decreased with the increase of millet flour replacement. The highest value of gumminess was recorded in sample C (4.27 N). While the least values were recorded in gumminess for T4 (2.38N). Chewiness is a textural property that can be readily correlated with trained panels and sensory assessments. Gumminess and chewiness are two criteria that depend on firmness; as a result, their values in fresh cakes follow a similar trend to the firmness trend.

It was noticed that there were significant differences ($p < 0.05$) between the samples in chewiness. Sample C revealed the highest value for chewiness (2.45 N), then chewiness decreased with the increase in the amount of millet flour in the samples where T4 sample recorded the lowest value (1.88 N). The optional results are in consistent with those of *Nada et al.* [36] who reported that these parameters decreased with increasing of germinated millet addition compared control. *Mitharwal and Chauhan* [32] reported that chewiness reduced in muffins prepared from 100% finger millet flour as compared with refined wheat flour control muffins.

Resilience and springiness are measures of the ability of a sponge to recover after compression [38]. In the fresh cupcake, sample T4 recorded the lowest value of resilience being (0.29 mm) whereas C recorded the highest value (0.31 mm) with no significant differences ($p > 0.05$). The sample C recorded the highest value for springiness (0.66 mm), and the sample T4 recorded the lowest value of (0.57 mm). These results agree with those reported by *El Tanahy et al.* [9].

Table (5): Texture attributes of gluten free Cupcakes produced by rice flour, xanthan gum and cactus mucilage powder.

Cupcakes treatments	Firmness (N)	Cohesiveness (N)	Gumminess (N)	Chewiness (N)	Springiness (mm)	Resilience (mm)
C	8.12±0.22[a]	0.51±0.10[a]	4.27±0.06[a]	2.45±0.05[a]	0.66±0.02[a]	0.31±0.03[a]
T1	6.67±0.09[b]	0.63±0.02[a]	3.76±0.05[ab]	2.26±0.20[b]	0.62±0.03[ab]	0.30±0.04[a]
T2	5.01±0.08[c]	0.65±0.09[a]	3.40±0.58b[c]	2.12±0.16[bc]	0.61±0.03[bc]	0.300.01[a]
T3	5.10±0.11[c]	0.66±0.02[a]	3.18±0.07[c]	2.02±0.02[cd]	0.58±0.02[bc]	0.30±0.02[a]
T4	5.21±0.09[c]	0.69±0.06[a]	3.23±0.06[bc]	1.88±0.03[d]	0.57±0.30[c]	0.29±0.03[a]

Each value is mean of three replicates. Means within a column marked with different letters are significantly different at (p<0.05). **RF**: Rice flour, **PMF**: Pearl millet flour, **CMP**: Cactus mucilage powder. **C** (control): 100% RF + 2% CMP, **T1**: 75% RF + 25% PMF + 2% CMP, **T2:** 50% RF + 50% PMF + 2% CMP, **T3:** 25% RF + 75% PMF + 2% CMP, **T4**: 100 % PMF + 2% CMP

3.4. Sensory evaluation

Sensory attributes are a key factor in estimating the acceptability of processed product [39]. Thus, cupcake samples sensory assessment was assessed in terms of crust color, texture, crumb porosity, aroma, taste, appearance, and overall acceptability. Effects of different replacement levels of PMF on sensory properties of gluten-free cupcakes (C, T1, T2, T3 and T4) are presented in Fig. 2. The results indicated that all samples were acceptable. The highest value for crust color was observed in sample T2 (7.6) and the lowest value was observed in sample T4 (6.2). Sample T2, T3 recorded the highest values of texture (7.8) and (7), respectively while the lowest value for texture was observed in sample T4 (6.2). Sample T2, T3 recorded the highest values of crumb porosity (7.8) and (7), respectively while the lowest value for crumb porosity were noticed in T4 (6.2). Furthermore, sample T2 recorded the highest value (8) for aroma and the lowest was noticed in T4 (6.6).

There were no significant differences ($p \geq 0.05$) in the taste, appearance, and overall acceptability of all samples. The most acceptable sample was T2 followed by T3, T1, and C while T4 was the lowest accepted ones. *Nada et al.* [36] reported that samples which contained 50% rice flour and 50% germinated millet flour have the highest score for all the evaluated sensory characteristics and were significantly different compared to other treatments. According to *Hassan et al.* [15], the sample with the highest scores for all assessed features contained 34 g of millet flour + 34 g of rice flour + 32 g of rice starch. In contrast, the sample with 100% millet flour had a lower acceptability score than the others. Similarly, *Khorasani et al.* [35] found that the sample with the highest sensory acceptance was 50% rice flour and 50% millet flour with 0.15% xanthan gum.

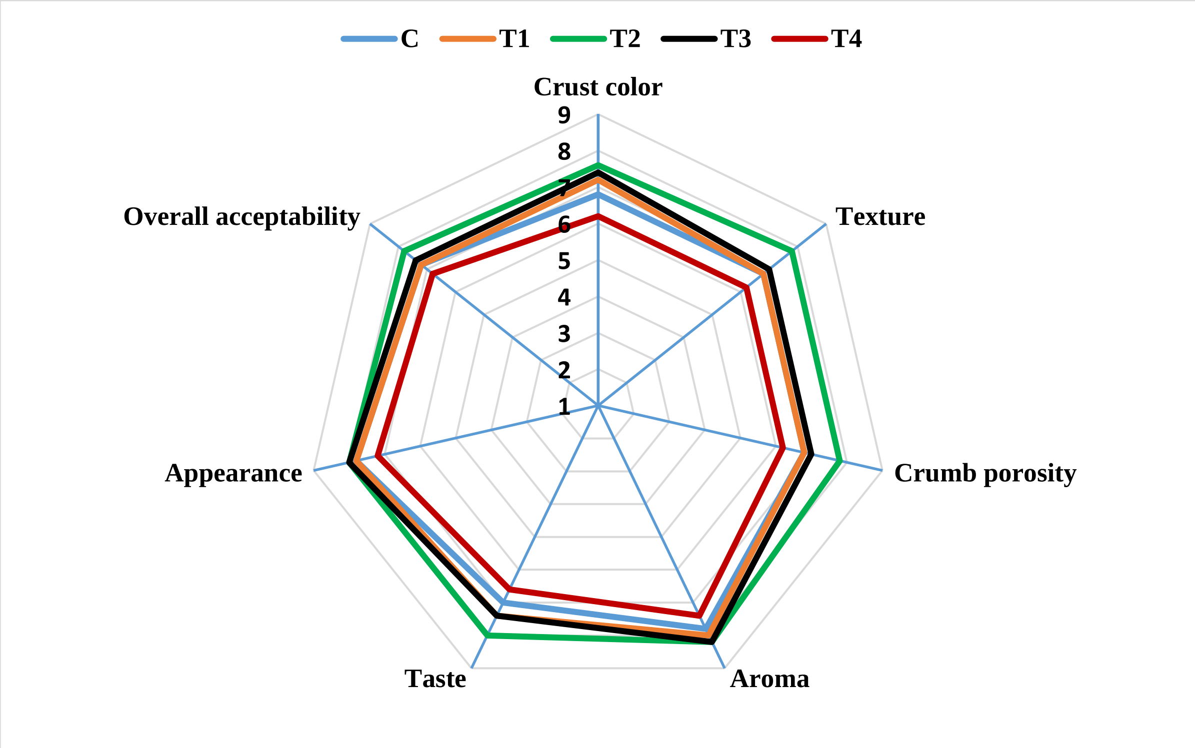

Fig. 2. Sensory evaluation scores of GF cupcakes produced from RF, PMF and CMP C (control): 100% RF + 2% CMP, T1: 75% RF + 25% PMF + 2% CMP, T2: 50% RF + 50% PMF + 2% CMP, T3: 25% RF + 75% PMF + 2% CMP, T4: 100 % PMF + 2% CMP.

4. Conclusion

This study proved that it is feasible to utilize the mucilage from *O. ficus-indica* as a natural hydrocolloid in the manufacturing of gluten-free cupcake. Results revealed that gluten free cupcake produced with pearl millet flour had a higher content of protein, ash, fat, and fiber compared to control (100% rice flour). Additionally, the sensory characteristics of cupcake sample containing 50 % RF+ 50% PMF + 2% CMP were the most acceptable formulae among the investigated treatments. Texture profile results showed that substitution with PMF decreased firmness, cohesiveness, gumminess, chewiness, springiness, and resilience of cupcake samples than control samples. Therefore, this study recommends using PMF and CMP as a functional ingredient in the manufacturing of GF bakery products.

5. Competing Interests

The authors declare that they have no competing of interests in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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