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GLUTEN-FREE RICE MUFFINS ENRICHED WITH TEFF FLOUR

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ABSTRACT

In recent years, demand for gluten-free products has grown. More and more people suffer from allergies, so the market should expand to products for this group of people. It is also important to improve the gluten-free nutritional content diets by incorporating alternative gluten free grains that are naturally rich in nutrients. Teff is a valuable ingredient of gluten-free products because it increases their nutritional quality. Teff is rich in fibre, carbohydrates and has a complete set of essential amino acids, is also high in iron and has more copper, zinc and calcium than other cereal grains. The effect of teff flour addition (25, 50 and 75%) to rice muffins on qualitative and sensory parameters was evaluated. The antioxidant activity of raw materials and products was also determined. Utilization of teff flour up to 50% provided satisfactory results. Incorporation of higher addition levels of teff flour (75%) negatively affected qualitative and textural properties of muffins; the muffins were harder, crumbly and less springy. High antioxidant potential of teff was reflected in increasing antioxidant activity of baked products. Muffins enriched with teff flour had pleasant flavor, sweet and nutty taste. Sensory evaluation revealed that rice muffins incorporated with teff flour at level 25% were the most acceptable for assessors.

Keywords: muffin; gluten-free; teff flour; rice flour, sensory

INTRODUCTION

In recent decades, gluten has attracted great attention due to the increasing number of diagnosed patients with intolerance to this protein fraction, relating to the improved sensitivity of the detection methods and the increasing awareness of the existence of the disease. Three pathologies are associated with gluten intake, which appear to be increasing in importance: i) food allergy, ii) coeliac disease, which is an autoimmune disorder caused by the ingestion of gluten not only from wheat, but also rye, barley and some varieties of oats and iii) gluten sensitivity, a pathology of intolerance to gluten **(Rosell et al., 2014)**.

Celiac disease is a cell-mediated autoimmune disease whereas wheat allergy is an immunoglobulin E (IgE) – mediated reaction. The symptoms of these disorders may vary, depending on individual sensitivity and disease severity. Celiac disease causes villous atrophy of the small intestine, resulting in various gastrointestinal and extraintestinal/systemic complications. Like other food allergies, depending on the severity, the symptoms of wheat allergy may range from mild itching to life-threatening anaphylaxis. Since there is no cure available, avoidance of gluten/wheat in the diet is the best option for patients **(Sharma, Pereira and Williams, 2015)**. The production of high-quality leavened baked goods made from ingredients other than wheat flour represents a major technological challenge, due to the absence of the visco-elastic gluten compound **(Hager and Arendt, 2013)**.

Teff is a cereal native to Ethiopia and Eritrea. It has an excellent adaptability to harsh environmental conditions and plays an important role in food security. In recent years, teff is becoming globally popular due to the attractive nutritional profile such as gluten free and high dietary fiber content **(Zhu, 2018)**.

Teff (*Eragrostis tef*) is a tropical cereal that belongs to the family of *Poaceae*, subfamily *Eragrostoidae*, tribe *Eragrosteae* and genus *Eragrostis*. About 350 species are known in the genus *Eragrostis*, of which teff is the only cultivated species **(Gebremariam, Zarnkow and Becker, 2014)**. There are about 33 improved tef varieties and hundreds of farmers' local varieties in Ethiopia, differing in seed size and color from milky-white to almost dark-brown **(Shumoy and Raes, 2017)**. For marketing purposes, teff is classified on the basis of seed color: netch (white), qey (red/brown) and sergegna (mixed) **(Gebremariam, Zarnkow and Becker, 2014)**.

Teff is the smallest grain in the world, taking 150 grains to weigh as much as one grain of wheat. The extremely small grains are 1 – 1.5 mm long and there are 2500 – 3000 seeds to the gram. Because of its small size, teff is made into whole-grain flour (bran and germ included), resulting in a very high fiber content and high nutrient content in general **(Mohammed, Mustafa and**

Osman, 2009; Gebremariam, Zarnkow and Becker, 2014).

Teff grain is gluten free and has great potential to be formulated into a range of food/beverage products to aid people with celiac disease. As a result of the unique chemical composition and the whole grain form, a range of health benefits have been associated with teff. For example, teff showed in vitro anti-oxidative activities, and can improve the haemoglobin level in human body and help to prevent malaria, and incidence of anaemia and diabetes **(Zhu, 2018)**.

Scientific hypothesis

The purpose of this study was to prepare gluten-free muffins with known additions of teff flour, determine the physical and textural properties of muffins, the antioxidant activity and the color of individual raw materials and products. It was also important to perform a sensory analysis of finished products.

MATERIAL AND METHODOLOGY

Fine rice flour (moisture 8.17%), whole grain teff flour (moisture 9.56%) and other ingredients (vegetable oil, salt, sugar, milk, eggs and baking-powder) were purchased in local market.

Muffins were prepared according to **Tess et al. (2015)**. Rice flour was replaced with 0%, 25%, 50% and 75% teff flour. Milk (174.2 g), oil (53.4 g) and egg (76 g) were mixed together with an electric hand mixer. Flour (200 g), sugar (51 g), baking powder (5.6 g) and salt (4 g) were mixed together in a separate bowl, and then were mixed into with the wet ingredients. Muffin pans were filled with the butter and were baked for 21 minutes at 190°C in a preheated oven (Mora MB05103GX, Czech Republic). Then were muffins removed from the pans and allowed to cool on wire racks for one hour after which analyses were performed. Baked muffins are presented in Figure 1.

Qualitative parameters of muffins

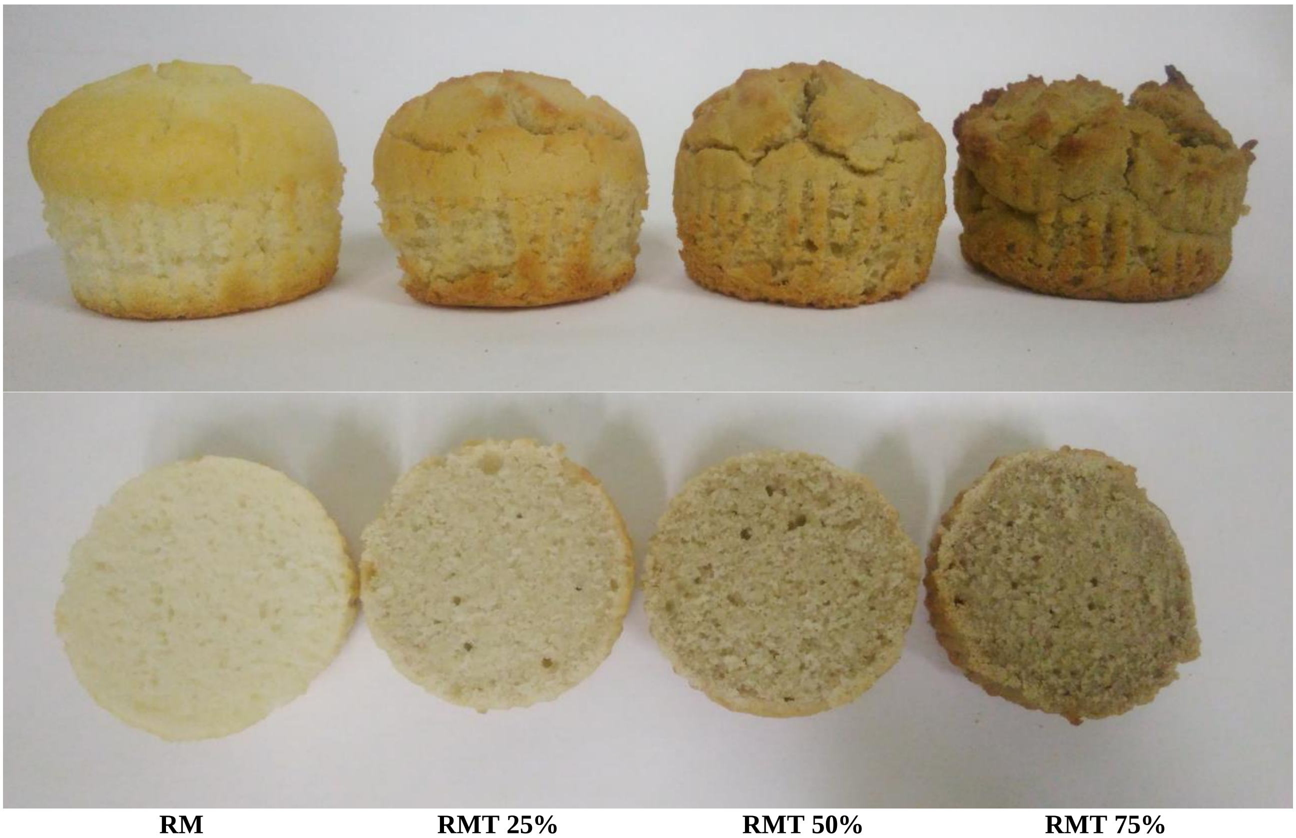
Qualitative parameters of muffins were evaluated 2 h after baking.

The muffin height and width was measured from the highest part of the muffin to the bottom part and at the widest point using a calliper **(Martínez-Cervera, Salvador and Sanz, 2015)**.

Cambering of muffins was calculated as a ratio of muffin height and width **(Lauková, Kohajdová and Karovičová, 2016)**.

Moisture of muffins was determined according to method AACC 44-19.01 **(AACC, 2000)**.

Baking loss (%) is characterized as the muffin weigh reduction after baking. The muffins were weighed before (W3) and after baking and 2 h cooling (W4). The weighting mean mass loss during baking was calculated as follows: weight loss = (W3-W4)*100/W3 **(Martínez-Cervera, Salvador and Sanz, 2015)**.



RM **RMT 25%** **RMT 50%** **RMT 75%**

Figure 1 Photo of muffins.
Note: RM – rice muffins without teff flour. RMT – rice muffins with teff flour (25, 50 and 75%)

Textural analysis

Muffin firmness was determined according to modified method described by **Acosta, Cavender and Kerr (2011)** using a texture analyzer (TA-XT Plus, Stable Micro Systems, Godalming, Surrey UK). Firmness and springiness were measured using Method MUF1/P36R. Firmness was defined as the force (in grams) required compressing the product by a pre set distance. A simple way of looking at the springiness property is to record the force after 30 seconds and divide this by the maximum force and then multiply by 100%. The closer the resulting value is to 100% the more like a „spring“ the product is. Cross sections of 2.5 cm thickness were cut from the center of each muffin and subjected to a modified compression test fitted with a 36 mm diameter cylindrical probe. Each sample was compressed to 40% of the sample's initial height at a probe speed of 1.0 $mm.s^{-1}$.

The textural profile analysis (TPA) was conducted on the muffins using a texture analyzer. The quality attributes measured were hardness, springiness, cohesiveness and chewiness **(Gupta, Sharma and Sharma, 2007)**. Hardness is defined as the maximum peak force during the first compression cycle (first bite). Springiness is related to the height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite. Cohesiveness is defined as the ratio of the positive force during the second compression to that during the first compression **(Tess et al., 2015)**. Chewiness is obtained by multiplying harness, cohesiveness and springiness **(Cornejo and Rosell, 2015)**. Gumminess is defined as a product of hardness x cohesiveness **(Bourne, 2002)**. The test was performed on cubes (2.5 cm side) taken from the center of the muffin. The test speed was 1.7 $mm.s^{-1}$; the post test speed was 10 $mm.s^{-1}$ and there was a 5 s interval between the two compression cycles. A trigger force of 5 g was selected. The compression of 40% was performed with a 36 mm cylindrical probe, and the cubes were compressed twice **(Tess et al., 2015)**.

Color measurement

The color was determined using a Cary 300 Spectrophotometer (Agilent Technologies, USA). The color of the rice flour, teff flour and muffins from these flours was measured. A crumb of muffins was dried and grinded with a kitchen robot (Eta 0010, Czech Republic) before measuring. The individual color values were expressed using CIELab* and Metric L*Ch*. The color parameters were L* (L* = 0, black and L* = 100, white), a* (-a* = greenness and +a* = redness), b* (-b* = blueness and +b* = yellowness), C – Chroma and h* – hue angle. The spectrophotometer was calibrated with a white calibration tile **(Kraithong, Lee and Rawdkuen, 2018)**. The total color difference (ΔE) was determined using the equation according to **Ghanem et al. (2012)**.

Determination of antioxidant activity

Antioxidant activity was evaluated by measuring free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging capacity according to **Cai et al. (2014)**. Sample (0.1 g) was extracted with 1 mL of pure methanol at 25 °C for 2 h with continuous shaking under a dark environment and centrifuged at 1,200 × g for 10 min. The extract (0.05 mL) was reacted with 1 mL of 0.1 mM DPPH solution at 25 °C for 30 min, and absorbance was measured at 517 nm. Antioxidant activity was calculated as percent discoloration of DPPH = $[1 – (A1/A0)] \times 100$, where $A1$ is the absorbance of sample extract at the end of the reaction (t = 30 min) and $A0$ is the absorbance of the pure methanol control at the beginning of the reaction (t = 0). Measurements were conducted in duplicate, and the data were reported as percentage of discoloration.

Sensory evaluation of muffins

The sensory evaluation of muffins was made by five point hedonic scale which ranged from 5 = most liked to 1 = most disliked. The panel was made up of staff and students of the Faculty of Chemical and Food Technology, Slovak University of Technology, Bratislava, Slovakia. The overall acceptability of muffins was determined using 100 mm graphical non-structured abscissas with the description of extreme points (minimal or maximal intensity, from 0 to 100%) according to **Lauková, Kohajdová and Karovičová (2016)**.

Statistic analysis

All measurements were carried out in triplicate and the average values were calculated. The results were expressed as mean value ± standard deviation. Significant differences between mean values at significance level p <0.05 were compared using Student`s test. Microsoft Excel version 2010 was used as the statistical analysis software.

RESULTS AND DISCUSSION

The qualitative (cambering, moisture and baking loss) and textural (firmness and springiness) parameters of muffins are shown in Table 1.

The cambering value of control sample (RM) was 0.79. From the results concluded that addition of teff flour increased the cambering of muffins up to 0.88 (RMT 75%).

Moisture content of muffins showed no significant differences after addition 25 – 50% of teff flour. Addition of 75% of teff flour increased muffins moisture to 41.20%. A high level of moisture content may be indicating short self life of composite muffins as they encourage microbial growth leads to spoilage **(Man et al., 2014)**.

Determining the actual baking losses is very important as the finished product after baking must have a defined weight. The loss by baking is influenced mainly by the weight of the product; by shape and moisture content **(Minarovičová et al., 2018)**. Increasing level of teff flour caused decreasing of baking loss values.

In baking industry, the products having a specific shape and definite texture determine the acceptance or rejection of the product by the consumers. Texture of product shows its quality **(Younas et al., 2015)**. Texture evaluation demonstrated that muffins including 25 and 50% of teff flour had similar firmness compared to control sample (RM). However, the 75% replacement of rice flour resulting in 39.15% increase of muffin firmness. Similar trend was observed when the hardness was measured using TPA (Table 2). Comparable results were also described by

Table 1 Qualitative and textural parameters of muffins.

	Cambering	Baking loss (%)	Moisture of crumb (%)	Firmness (g)	Springiness (%)	Overall acceptance (%)
RM	0.79 ±0.01	18.18 ±0.36	40.07 ±0.14	3278.92 ±164.00	62.51 ±1.13	91.73 ±5.15
RMT 25%	0.78 ±0.02	20.42 ±0.69	39.91 ±0.59	3452.83 ±170.04	57.58 ±1.30	91.10 ±2.34
RMT 50%	0.81 ±0.02	17.51 ±0.67	40.27 ±0.52	3536.74 ±168.88	54.60 ±0.79*	90.40 ±5.92*
RMT 75%	0.88 ±0.04*	15.92 ±0.70*	41.20 ±0.16*	4562.75 ±169.26*	49.73 ±1.61*	79.60 ±8.33*

Note: RM – rice muffins without teff flour, RMT – rice muffins with teff flour (25, 50 and 75%), * denotes statistically significant difference at *p* <0.05 level.

Table 2 TPA parameters of muffins.

	Hardness (g)	Gumminess	Chewiness	Springiness	Cohesiveness
RM	5534.36 ±239.64	3752.88 ±177.28	3716.79 ±127.88	0.95 ±0.00	0.67 ±0.00
RMT 25%	5642.03 ±184.51	3747.68 ±209.43	3482.48 ±196.98	0.93 ±0.01	0.64 ±0.01
RMT 50%	5562.78 ±266.82	3071.74 ±231.41*	2713.38 ±193.85*	0.88 ±0.03*	0.55 ±0.02*
RMT 75%	6329.06 ±185.45*	2589.47 ±11.85*	2067.76 ±30.77*	0.79 ±0.01*	0.42 ±0.00*

Note: RM – rice muffins without teff flour, RMT – rice muffins with teff flour (25, 50 and 75%), * denotes statistically significant difference at *p* <0.05 level.

Table 3 Color parameters of raw materials and muffins.

	L*	a*	b*	C	h*	ΔE
RF	89.06 ±0,05	0.11 ±0.00	5.18 ±0.01	5.18 ±0.01	88.74 ±0.01	-
TF	73.56 ±0,10	2.09 ±0.00	12.97 ±0.05	13.14 ±0.04	80.86 ±0.04	-
RM	77.81 ±0.05	1.38 ±0.03	14.44 ±0.13	14.51 ±0.13	84.52 ±0.06	-
RMT 25%	72.33 ±0.02	2.14 ±0.01*	16.37 ±0.04*	16.51 ±0.04*	82.57 ±0.02*	17.19 ±0.13
RMT 50%	68.00 ±0.11*	2.85 ±0.02*	16.96 ±0.24*	17.20 ±0.24*	80.47 ±0.06*	52.49 ±1.76
RMT 75%	64.58 ±0.05*	3.13 ±0.01*	16.01 ±0.01*	16.31 ±0.01*	78.93 ±0.03*	90.42 ±0.70

Note: RF – rice flour, TF – teff flour, RM – rice muffins without teff flour, RMT – rice muffins with teff flour (25, 50 and 75%), * denotes statistically significant difference at *p* <0.05 level.

the authors **Tess et al. (2015)** in muffin enriched with teff flour.

Springiness is associated with freshness in a product with a high quality muffin having higher springiness values **(Tess et al., 2015)**. The increase in the muffin firmness is related to the decrease in muffin springiness. With higher addition levels of teff flour the muffins were less springy.

TPA parameters of muffins are summarized in Table 2. Gumminess is defined as the energy required to disintegrate a semisolid food to a state of readiness for swallowing **(Bourne, 2002)**. In this study was observed that addition of teff flour at higher levels (50 and 75%) caused significantly lower gumminess of muffins.

Springiness is a measurement of how much the crumb springs back after being compressed once and it can be defined as the elasticity of the crumb, it is also an important parameter to determine the staling degree of product **(Lauková et al., 2017)**. Substituting of rice flour in muffins with teff flour resulted in lower springiness, similarly to the protocol MUF1/P36R which was used in textural analysis.

Cohesiveness is defined as how well the product withstands a second deformation relative to how it behaved under the first deformation **(Boz and Karaoğlu, 2013)**. It was noticed that muffins with 25% of teff flour had comparable cohesiveness with control sample (RM). Higher substitution levels caused lower cohesiveness. These results are in agreement with study of **Tess et al. (2015)**.

Chewiness is related to the work needed to chew a solid sample to a steady state of swallowing **(Boz and Karaoğlu, 2013)**. Results in Table 2 also showed that increasing level of teff flour led to significantly lower chewiness of muffins.

The color of bakery products is affected by ingredients, process, and ingredient process interactions, such as Maillard or caramelization reactions **(Kırbaş, Kumcuoglu and Tavman, 2019)**. Color also depends on the concentration of a certain ingredients **(Bhadury, 2013)**. Rice flour is white in color and teff flour can range in color from ivory to light brown. This fact was confirmed with result presented in the Table 3. The highest lightness (L*) was observed in rice muffins (RM). Significant decrease of this parameter was detected in samples containing 50 and 75% of teff flour, which is the consequence of darker color of initial teff material. Incorporation of teff flour caused in higher a* and b* color parameters. Chroma (C*), considered the quantitative attribute of colorfulness, is used to determine the degree of difference of a hue in comparison to a grey color with the same lightness. The higher the C* value, the higher is the color intensity of samples perceived by humans **(Granato and Masson, 2010)**. Higher color intensity (C*) of muffins was related to high C* value identified in teff flour. These findings are reflected in color differences (ΔE), which had increasing trend up to 90.42 (RMT 75%).

The antioxidant activity (percentage of discoloration) was measured in raw material and also in baked products

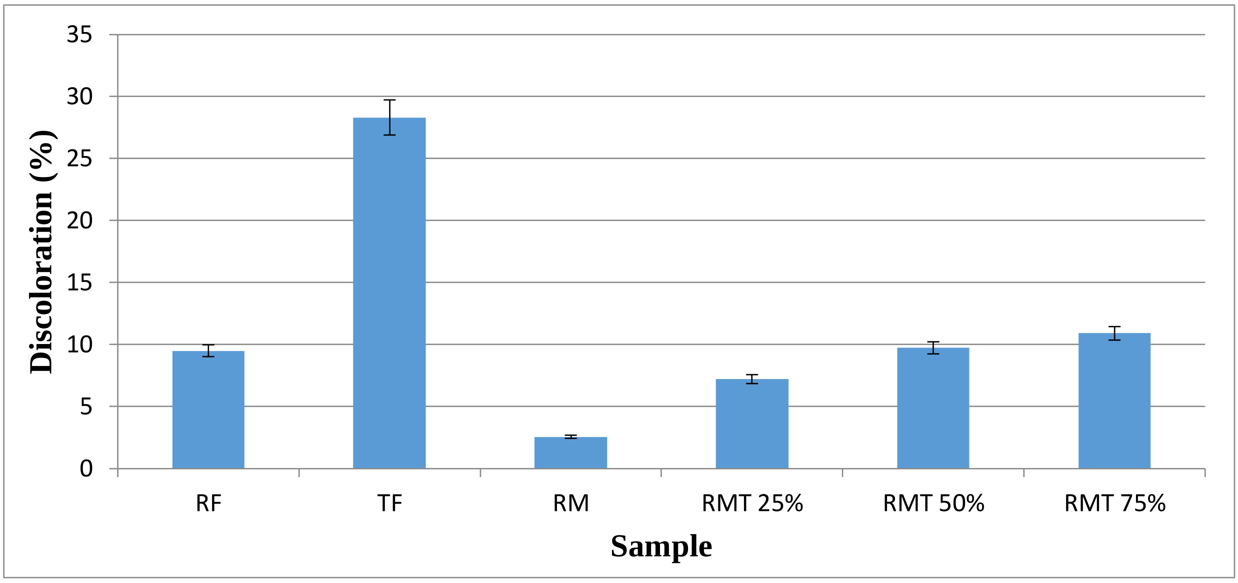


Figure 2 Antioxidant activity of raw materials and muffins.
Note: RF – rice flour, TF – teff flour, RM – rice muffins without teff flour, RMT – rice muffins with teff flour (25, 50 and 75%).

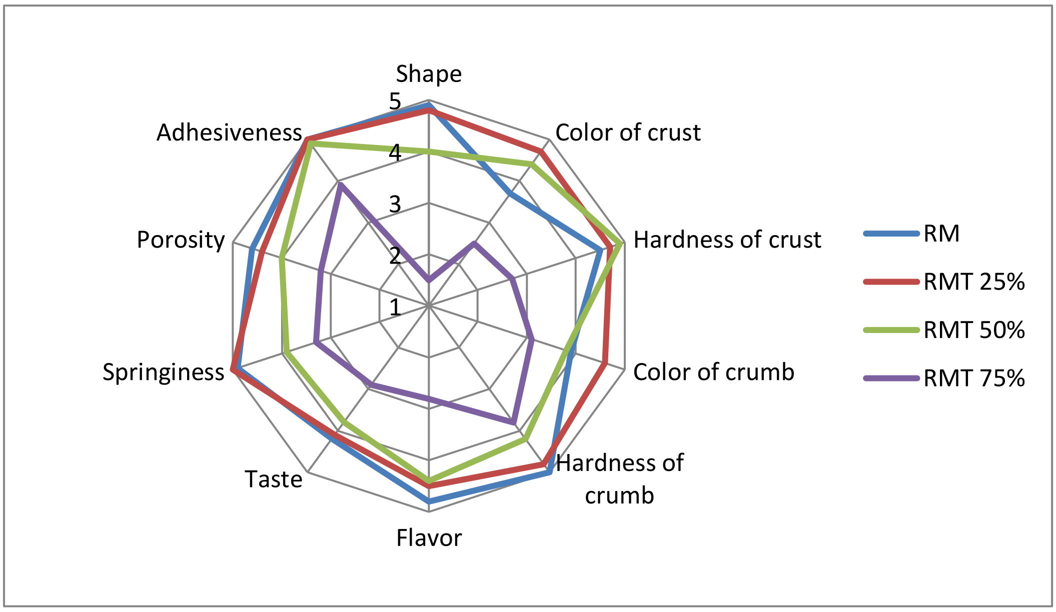


Figure 3 Sensory evaluation of muffins.
Note: RM – rice muffins without teff flour. RMT – rice muffins with teff flour (25, 50 and 75%)

(Figure 2). As can be seen from the results, teff flour had about 3-times higher antioxidant activity (28.32%) than rice flour (9.51%). Thereupon the teff enriched muffins also had higher antioxidant activity (7.22 – 10.91%). The effects of teff flour on sensory parameters of muffins are presented in Figure 3. Generally, teff supplementation of rice flour resulted in decreasing of shape score of muffins. The highest addition level of teff led to cracked and less compact shape of muffins. Color is an important attribute of the baked food products because it affects to the consumer's perception to the acceptability of the product **(Bhadury, 2013)**. The results showed that color of enriched muffins, both for crust and crumb, was more acceptable for assessors up to addition level 50% than control sample (RM). The score for flavor of muffins was not significantly affected by teff addition, except for sample including 75% of teff. The muffins enriched with 25 and 50% of teff flour had similar sensory score of taste with control sample (RM). Moreover, the assessors describe the pleasant sweet and nutty taste of teff incorporated muffins. The assessors also described that muffins contained high levels of teff were harder and less springy compared to control sample (RM). Results also showed that incorporation of teff at higher levels caused that muffins had less porosity.

The overall acceptance results of muffins are summarized in Table 1. It was concluded that the most acceptable enriched muffins (91.10%) were prepared with 25% of teff flour, which was comparable with overall acceptability of control sample RM (91.73%), while higher supplementation level caused the lower acceptance of muffins. Similar decreasing trend was described by **Tess et al. (2015)** for rice muffin enriched with teff flour.

CONCLUSION

In this study it was noticed that lower addition of teff flour in the muffins had similar quality parameters like control rice muffins. Moreover, enriched muffins had better color, flavor and taste. In general, it was concluded that muffins with acceptable qualitative and sensory parameters can be prepared by addition of teff flour at level 25 and 50%.

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