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RESEARCH ARTICLE

Effect of bakery fat substitution by ghee residue on the quality characteristics of pearl millet based biscuit

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Abstract: Conventionally bakery products are prepared from wheat and its derivatives. Awareness of the allergy and health complications associated with gluten and refined wheat flour, leads to increased consumption of gluten-reduced or gluten free products. Pearl millet flour is rich in dietary fiber, protein and minerals. Pearl millet has been used in this investigation to partially replace refined wheat flour. In this study, pearl millet flour and refined wheat flour were taken in a ratio of 1:1. Ghee residue (GR) is a by-product that is nutrient dense and possesses flavouring properties. The underutilised product is a source of fat, protein and phospholipid, and may find application in chocolate, burfi, sweets and bakery products. GR is used as a fat replacer in the preparation of biscuits. Fat substituted with GR at 0, 10, 15, 20 and 25% levels. The effect of fat substitution with GR on proximate physical, textural and sensory properties was studied. It reveals the colour (L*) and hardness of the biscuit increased with GR substitution whereas the percentage of fat, redness, browning index and some sensorial properties decreased. Descriptive sensory analysis reveals that biscuits are distinguished from coarseness, browning appearance, toasted and sweet flavour.

Keywords: Biscuits, Fat substitution, Ghee residue, Pearl millet

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Introduction

Bakery and confectionery products have gained attention in the last 2 decades due to changes in lifestyle and food habits. Busy lifestyle, nuclear family, all working members in a family, urbanization and Western influence attract convenience and fast foods. According to IMARC (2023) reports, the global bakery market size reached USD 497.5 billion in 2022 and is expected to increase at 3.7% CAGR during 2023-2028 to reach USD 625.9 billion by 2028. These products are highly valued compared to other products due to their availability in various types, packaged and convenient food consumption and low cost. The whole world witnessed during covid period that the food market never fell. So, it is important to notice that even in emergencies like natural calamities and disasters, products play a very important role in relieving hungriness in people.

Wheat is the main raw ingredient used as a base material in the preparation of a variety of bakery products. Generally, soft wheat flour with low protein (7-11%) is preferred for making biscuits, as hard wheat produces tougher biscuits (Pauly et al. 2013). Soft wheat flour has finer granulation, less starch damage and lower water absorption than hard wheat flour (Barak et al. 2014). Wheat flour contains gluten protein, which contributes to a peculiar viscoelastic property of a dough, which is essential for the formation of protein-starch networks and trapping carbon dioxide (Islam et al. 2019). It is quite difficult to prepare a product without gluten, but it causes allergies to people. The prevalence of gluten allergy limits the consumption of wheat-derived bakery products. There are many alternatives to wheat such as rice, maize, pseudo cereals and millet, which are gluten-free in nature. Millets are considered Nutri cereals as they are nutritionally superior and rich in dietary fibers and many bioactive compounds.

Pearl millet (*Pennisetum glaucum*) is a multipurpose cereal grown for food, feed, and fodder, especially in African and Asian countries (Manwaring et al. 2016). Pearl millet is known as "Nutri-cereal" due to its high fibre, protein, fat (rich in unsaturated fatty acids) and mineral composition. The protein made up of pearl millet lacks gluten proteins making it an ideal alternative food for celiac and gluten-intolerant people (Asrani et al. 2023). Pearl millet has carbohydrates of 60-62%, protein of 9-11% and lipids of 5-

7%. Various cohort workers prepared pearl millet biscuits (Mehra and Singh, 2017). Textural properties such as chewiness, hardness, gumminess, breaking strength and cutting strength of biscuits increased with the replacement of wheat flour as observed by Kulkarni et al. (2021). Kulthe et al. (2017) reported that replacing wheat flour with pearl millet flour caused a decrease in the diameter and spread ratio of biscuits, while the thickness of the biscuits improved. The colour values of muffins were considerably decreased with a 50% replacement of wheat flour with pearl millet in muffins (GM et al.2024).

Biscuits are high-fat and high-sugar products (Moriano et al. 2018). Since fat is responsible for the flavour, texture, and aesthetic quality of the finished product, reducing and replacing fat is a significant challenge for researchers. A wide range of ingredients is being used as fat substitutes such as carbohydrates, proteins, fat and gels, which provide distinct attributes to the product. Also, it is crucial to consider how well these replacements work so that they can be compared to standard products. Sudha et al. (2007) reported that with the reduction of fat level, the biscuit dough becomes stiffer, more springer and more cohesive. Physical properties such as the spread of biscuits reduced and the breaking strength of biscuits increased. Arepally et al. (2020) reported that the texture of low-fat cookies increases in cookie's hardness and brittleness with the replacement of fat. Aggarwal et al. (2016) formulated low-calorie biscuits using polydextrose as a fat replacer, the prepared biscuit had a lower sensory score compared to a biscuit made from full fat.

Taking into account the difficulties in the preparation of biscuits from fat replacers, an underutilized dairy by-product called ghee residue is utilized to substitute bakery fat. The by-product obtained is usually considered waste with no apparent economic value, but it is rich in fat and protein. GR is a rich source of natural flavour compounds like carbonyls, lactones and free fatty acids and its concentration is 10,132 & 11 times higher than ghee, respectively (Varma and Raju, 2008). GR is a good source of phospholipids (lecithin, cephalin, sphingomyelin and cerebroside) and nitrogenous compounds.

On an industrial scale, ghee residue is utilized in the production of certain food products and as a flavour enhancer (Wani, 2022). Traditionally, ghee residue has been widely used by mixing it with milk or skimmed milk powder, khoa, sugar and flavours for the preparation of sweets like chocolate, burfi, peda, pinni, toffees etc. and in certain food preparations like soups, spreads, muffin, etc. (Dua et al. (2018); Agrawal et al (2017); Janghu et al (2014); Singh and Rani (2019); GM et al. 2024). Rajan et al. (2020) attempted to prepare a cake and muffin by replacing refined wheat flour with GR (10-40 %). The cake & muffins made from 60% refined wheat flour and 40% GR had the highest overall acceptability. The body & texture, flavour and taste improved compared to the control sample (without GR) sample. The product was nutritionally better, especially in calcium content. Sojan et al. (2019) developed cookies and biscuits by replacing the bakery fat with GR. It was noticed that up to 10% shortening can be replaced with GR and that reduced the cost of production by ~16.6%.

The present investigation aims to prepare a biscuit using pearl millet and refined wheat flour and to substitute bakery fat with GR. Considering the nutrients, flavours and phospholipids present in GR, an attempt has been made to replace it with bakery fat. In this study, we mainly studied the effect of GR on the physicochemical and sensory properties of the biscuit.

Materials and Methods

Materials

Commercial pearl millet flour (moisture~ 6.53%, fat~5.62%. protein~9.14% & ash~1.66%) and refined wheat flour (moisture~9.33%, fat~1.67%, protein~9.88% & ash~0.65%) were supplied by the B.D Super Store market (Karnal, Haryana) and the proximate was carried out according to the AACC method. Fresh ghee residue (TS~28.19%, Fat ~8.18%, Protein~12.18% & Ash~1.49%) was procured from the Model dairy plant of ICAR-NDRI, Karnal (Haryana). Bakery fat- (Marvopride, Bunge India Pvt. Ltd., Mumbai) ground sugar, skim milk powder, salt, baking powder, ammonium bicarbonate, sodium bicarbonate and ammonium iron citrate were purchased from the local market.

Biscuit preparation

Composite flour was made using pearl millet flour (PMF) and refined wheat flour (RWF) in a 1:1 ratio. Biscuits were prepared using the creaming method (Raju et al. 2007) with a slight modification. Fat was substituted with ghee residue at 10%, 15%, 20% & 25% levels. The sample without the ghee residue was used as a control. Fat and sugar were creamed (40% of flour) to a cream consistency in a Hobart planetary mixer (M/sHobart Corporation, Ohio, USA). The GR, salt (1%) and ammonium iron citrate (2 ppm) were dissolved in water and added at the final stage of creaming. The accurately calculated amount of dry ingredients like flour (100 %), SMP (4%), baking powder (1%), ammonium bicarbonate (0.6%) and sodium bicarbonate (0.4%) were sieved to provide aeration and remove larger particles. These dry ingredients were added to the above cream and mixing continued at low speed until the dough reached a smooth homogeneous mass. The dough was rolled into a thin sheet of 2–3 mm thickness and 4 mm diameter using a wooden rolling pin and then cut into the desired shape using a biscuit cutter mould. The cut pieces were baked at 175°C for 13±3 minutes in the oven (Hcs Enterprises, Haryana).

Proximate analysis

Moisture, fat, protein and ash were carried out according to the AACC (1999) method and acid insoluble ash as per ISI (1989).

The acidity of the extracted fat was performed as described in IS SP: 18 (Part V) by ISI (1982).

Colour and water activity

A Tristimulus spectrophotometer Hunter Lab model Colour Flex® (MiniScan XE plus, Hunter Associates Laboratory Inc. Reston, Virginia, U.S.A.) was used to measure the colour of the biscuit and the results were expressed in terms of the CIE-LAB system. Measurement was carried out according to the method mentioned by Agrahar-Murugkar et al. (2015). The Aqua lab water activity meter (Model Series 3 TE) supplied by M/s Decagon Devices, WA, USA was used to determine the water activity of biscuits. The instrument was calibrated with charcoal then the sample readings were taken in triplicates. Three random readings of colour per sample were recorded and averaged. Furthermore, the values of L*, a*& b* were used to calculate the browning index of a biscuit (Isleroglu et al. 2012).

$$\text{Browning index} = \frac{100 \times \left(\frac{a + 1.79L}{5.645L + a - 3.012b} - 0.31 \right)}{0.17}$$

Spread ratio

The biscuits were physically evaluated by measuring their thickness and diameter. The thickness of the biscuits was determined by piling six biscuits and then taking their average value. Similarly, the diameter of six biscuits was measured and then their average value was taken. The spread ratio was calculated by taking the ratio of diameter to thickness.

Hardness of biscuit

Sample biscuits were evaluated for hardness using Texture analyser TA-HD plus (Stable Microsystems, USA) fitted with a 50 kg load cell. The equipment was fitted with HDP/BS blade and the biscuit was kept on the heavy-duty platform. Blade cuts the biscuits and the maximum force required to cut the sample was recorded. The test conditions were pre-test speed- 2 mm/s, test speed- 3 mm/s, post-test speed- 10 mm/s and distance- 10mm. The hardness of the biscuits was obtained by taking the absolute peak force from the cutting strength curve (Tyagi et al. 2007).

Sensory evaluation

The sensory evaluation of biscuits was evaluated by an expert panel of 10 judges on a 9-point hedonic scale in which a score of 1 represented 'dislike extremely' and a score of 9 represented 'like extremely' (Agrahar-Murugkar & Jha, 2011). The samples for evaluation were appropriately coded before serving the samples to the judges for sensory assessment. Evaluated parameters are taste, texture, colour, flavour and overall acceptability.

Statistical analysis

The data obtained from experiments were recorded as mean ± Standard deviation and subjected to statistical analysis to arrive at valid and meaningful influences. Data was analysed using one way-ANOVA. The least significant differences were calculated by the Tukey (HSD) test and the significance at $p<0.05$ was determined. Correlation was carried out using a partial correlation coefficient. These analyses were performed using SPSS for Windows Version 26.0. Principal component analysis was carried out using the R package 'factoextra'.

Results and Discussion

Proximate composition of biscuits

Biscuits and cookies are shelf-stable, low moisture, moisture-convenient products. The proximate composition of pearl millet-based biscuits is presented in Table 1. The moisture percentage of the biscuit samples ranged from 0.55% to 1.52%, moisture content of all treatments varied significantly ($p<0.05$) except between control and 20% GR biscuits. According to Sanni et al. (2018) to keep biscuits for a longer period and to reduce microbial proliferation, the moisture content of biscuits should be minimal. GM et al. (2024) observed an increase in the moisture trend of muffins with the addition of ghee residue powder. Moisture content increased due to high moisture content in GR and also proteins present in the GR held water during the baking process. The fat content of the biscuits ranged from 18.66 to 22.35%. Fat content was reduced ($p<0.05$) as GR levels increased in biscuit formulation due to lower GR fat levels (8.18%) than shortening (min. 80% fat). Borawake and Bhosale (1996) reported that the incorporation of GR decreased the fat content of biscuits. However, the acidity of the extracted fat increased slightly due to the presence of higher free fatty acids in the GR, but there was no significant increase in acidity ($p>0.05$) of extracted fat between the control and the biscuit made with 10% GR. GR had little effect on protein content because there was no significant change in the protein percentage of all biscuits ($p>0.05$). Florence et al. (2014) reported almost similar protein values for pearl millet cookies. Ash content shows the amount of minerals present in the biscuits and also the purity of the flour used in the preparation of the biscuits. Ash gradually increased with increasing GR levels, but there was not much significant difference in the ash content ($p>0.05$). The acid insoluble values signify the impure compounds and siliceous material present in the biscuits. Ranjan et al. (2020) reported a similar trend of increasing calcium content with the addition of ghee residue in a cake muffin product. It is evident from Table 1 that there is no adequate trend with an increase in ghee residue levels, but the values are significantly different from each other excluding 10% and 20% GR biscuits.

Colour and water activity of biscuits

Consumer acceptability purely depends upon the appearance of the product; if the product appeals aesthetic to the consumer, he/she decides to purchase it. Similarly, water activity is critical, as it determines the product's shelf life and texture. Colour is an important factor that talks about the amount of heat dissipation on biscuits. Surface colour is usually measured in terms of L*, a* and b* which is adopted internationally by the Commission Internationale d'Eclairage. Table 2 shows the colour of the biscuit samples expressed in terms of tri-stimulus characteristics, L*, a*, and b* values. According to the results, the colour values of all biscuit samples were significantly different (p<0.05). In Table 2, as GR levels increased, the lightness levels increased significantly (p<0.05), while the values of redness (a* values) and yellowness (positive b* values) values were gradually decreased. Biscuits incorporated with 25% GR had the highest lightness value (p<0.05), whereas the control biscuit had the lowest (p<0.05). The lightness increases with an increase in the GR as a result dilution of components. Bala et al. (2019) found that the addition of whey protein isolates to quality protein maize based muffins resulted in an increased lightness value. Colour development depends upon the individual components in a product composition and baking conditions (Lazaridou et al. 2007). As GR contains a higher moisture content, it reduces the browning reaction during the baking process leading to an increase in the lightness value of the biscuit. Redness and yellowness values of 10% GR biscuits were higher (p<0.05) than those of 25% GR biscuits while the water activity was highest (p<0.05) for 25% GR biscuits and lowest (p<0.05) for 15% GR biscuits. We can correlate the values of colour and water activity, as water activity increases, the values of a* (r= -0.794, p<0.001) and b* (r= -0.882, p<0.001) values decreased, and lightness increased. In the literature, no reports are available on the effect of GR on bakery-related products.

Another parameter, the browning index, provides a brief idea of the extent of heat treatment and acrylamide formation (Isleroglu et al. 2012). The colour of baked products is an important criterion for their preliminary acceptability. Furthermore, the amount of browning determines the flavour of the final product (Mundt and Wedzicha, 2007). The Maillard reaction and caramelization are primarily responsible for colour formation. Coloured compounds, such as hydroxy methyl furfural and melanoidins, accumulate during baking and depend on the compounds present

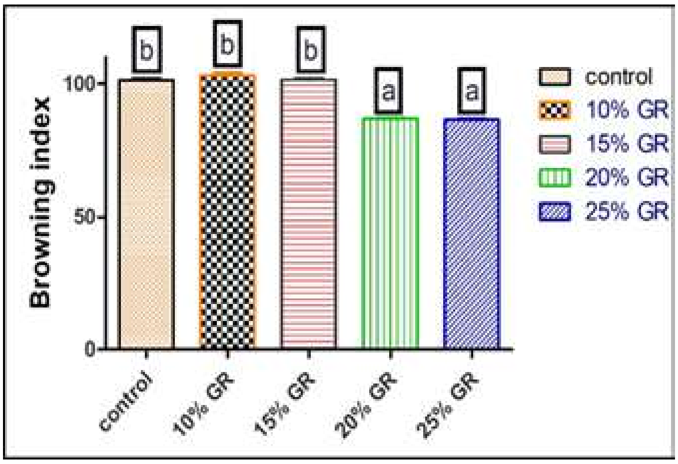


Fig 1. Browning index of biscuit samples

Note: control- Biscuit from Wheat: pearl-millet flour (50:50) with 100% shortening, 10% GR- 10 % fat replaced with ghee residue, 15% GR- 15 % fat replaced with GR, 20% GR- 20 % fat replaced with GR & 25% GR- 25 % fat replaced with GR

Table 1: Effect of different levels of GR on the proximate values of PM-based biscuit

Treatments	Moisture (%)	Fat (%)	Acidity of extracted fat (% oleic acid)	Protein (%)	Ash (%)	Acid insoluble ash (%)
Control	0.95±0.11^b	22.35±0.83^b	0.30±0.01^a	6.14±0.27	1.21±0.04	0.062±0.03^b
10 % GR	0.55±0.15^a	21.62±0.81^b	0.31±0.01^a	6.79±0.05	1.15±0.04	0.016±0.00^a
15% GR	0.66±0.04^{ab}	20.96±1.15^{ab}	0.33±0.02^b	6.86±0.89	1.17±0.05	0.026±0.00^{ab}
20% GR	1.01±0.10^b	19.21±0.79^a	0.34±0.00^b	6.44±0.80	1.19±0.04	0.033±0.00^a
25% GR	1.52±0.22^c	18.66±1.90^a	0.35±0.00^b	6.64±0.25	1.21±0.09	0.042±0.01^c

*Data are presented as Means ± S.D (n=3)

^{abc}Mean with different superscripts in different rows of a columns differ significantly (p<0.05)

Note: control- Biscuit from Wheat: pearl-millet flour (50:50) with 100% shortening, 10% GR- 10 % fat replaced with ghee residue, 15% GR- 15 % fat replaced with GR, 20% GR- 20 % fat replaced with GR & 25% GR- 25 % fat replaced with GR in the biscuit dough, the temperature, and the water activity of the system (Purlis, 2010). Baking time, moisture, dough composition, sugar, and protein content were all other considerations. However, over-baking results in the formation of toxic compounds like acrylamide and 5-hydroxy methyl furfural and its derivatives, which negatively impact consumer health (Mariotti Celis et al. 2017). A maximum value of 103.10 browning index was obtained for 10% GR and a minimum value of 86.48 was obtained for 25% GR (Fig.1). The browning index was reduced with the substitution of GR (p<0.05), which could be due to an increase in moisture content of the dough or a slight change in the composition of dough. Among the mean values of the biscuits control, 10% GR and 15% GR did not differ, whilst a higher level of ghee residue substitution, viz. 20% and 25% differ significantly (p<0.05) from a former biscuit (Figure 1). Leiva-Valenzuela et al. (2018) reported browning reduces with an increase in moisture content, as it affects the Maillard reaction.

Physical and textural properties of biscuits

The spread ratio is one of the most important quality parameters for biscuits as it defines characteristics related to texture, chewiness, and overall mouth feel (Bose and Shams-ud-din, 2010). It is evident from Figure 2 (a) that there is an increasing trend of spread ratio with ghee residue levels. The spread ratio ranged from 5.49 to 6.19 and all samples differed from each other (p<0.05) in their mean values except for 10% GR and 15% GR biscuits. As in Figure 2(a), the control had a spread ratio of 5.49, while the spread ratio increased to a maximum of 6.19 after the substitution of GR (25% GR). According to Florence et al. (2014), biscuits made from pearl millet flour have a low spread ratio. The spread ratio increased with an increase in GR substitution due to an increase in moisture content in the dough and a slight reduction in the fat content of the biscuits, as is evident from the fat content in Table 1.

The hardness of the biscuits was measured in terms of cutting strength. The effect of ghee residue levels on cutting strength is

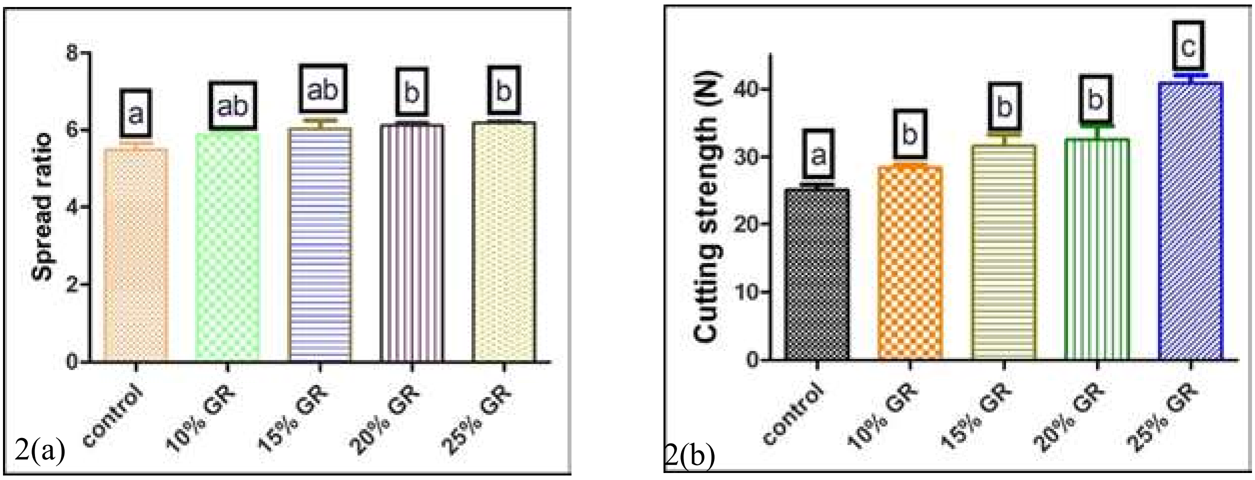


Fig 2. Effect of ghee residue substitution on (a) Spread ratio (b) Cutting strength
Note: control- Biscuit from Wheat: pearl-millet flour (50:50) with 100% shortening, 10% GR- 10 % fat replaced with ghee residue, 15% GR- 15 % fat replaced with GR, 20% GR- 20 % fat replaced with GR & 25% GR- 25 % fat replaced with GR

Table 2 Effect on colour and water activity of biscuits upon GR substitution

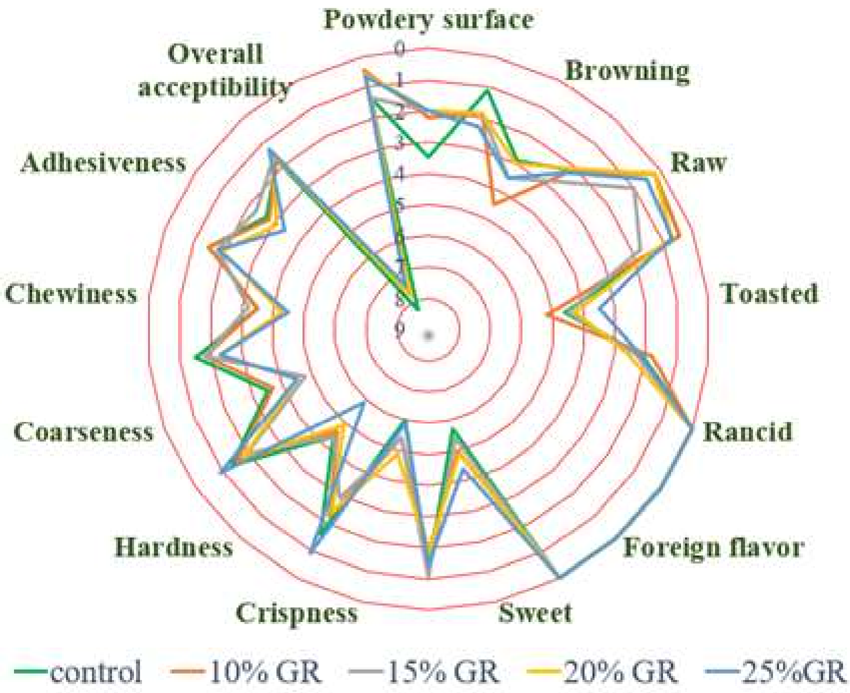
Treatments	L*	a*	b*	a_w
Control	49.51±0.42^{ab}	11.36±0.04^{b}	27.71±0.16^{c}	0.183±0.01^{b}
10 % GR	48.93±0.23^{a}	11.43±0.13^{b}	28.33±0.23^{d}	0.168±0.02^{a}
15% GR	49.82±0.24^{b}	11.11±0.05^{b}	27.49±0.27^{c}	0.164±0.01^{ab}
20% GR	50.81±0.14^{c}	09.90±0.06^{a}	26.40±0.13^{b}	0.171±0.00^{a}
25% GR	52.82±0.05^{d}	09.75±0.25^{a}	25.42±0.16^{a}	0.195±0.01^{c}

*Data are presented as Means ± S.D (n=3)

^{abc} Mean with different superscripts in different rows of columns differ significantly (p<0.05)

Fig 3. Sensory attributes of pearl millet-based biscuits

Note: control- Biscuit from Wheat: pearl-millet flour (50:50) with 100% shortening, 10% GR- 10 % fat replaced with ghee residue, 15% GR- 15 % fat replaced with GR, 20% GR- 20 % fat replaced with GR & 25% GR- 25 % fat replaced with GR



Control **10% GR** **15%GR** **20% GR** **25%GR**

Fig 4. Images of biscuits prepared from different levels of ghee residue and control

Note: control- Biscuit from Wheat: pearl-millet flour (50:50) with 100% shortening, 10% GR- 10 % fat replaced with ghee residue, 15% GR- 15 % fat replaced with GR, 20% GR- 20 % fat replaced with GR & 25% GR- 25 % fat replaced with GR

shown in Figure 2 (b). The control has a minimum cutting strength of 25.10 N whereas the maximum cutting strength is obtained with 25% GR substitution (40.89 N). The mean cutting strength values of the control and GR substituted biscuits differed significantly (p<0.05). However, the cutting strength of biscuits containing 10, 15 and 20% GR did not differ significantly from each other. The substitution of GR significantly increased the cutting strength of the biscuits (p<0.05) and this could be attributed to the reduction in the fat content of biscuits that resulted in increased hardness. A study by Chugh et al. (2015) found that the use of fat replacers increased the hardness and brittleness of cookies with fat replacement. Chugh et al. (2013) reported similar findings in which reducing fat levels increased the hardness of a composite biscuit. Gallagher et al. (2005) observed a higher hardness when sodium caseinate was used at 10 & 15%. They surmised due to the high water holding capacity and gelling capacity of sodium caseinate. In our experiment, the harder biscuits may be due to the protein and ash content of GR.

Sensory analysis of GR substituted biscuits

Descriptive sensory analysis is a standard tool that provides detailed information on the nature and intensity of sensory attributes as perceived by humans while djudging food (Omoba et al. 2015). The sensory characteristics of biscuits treated at

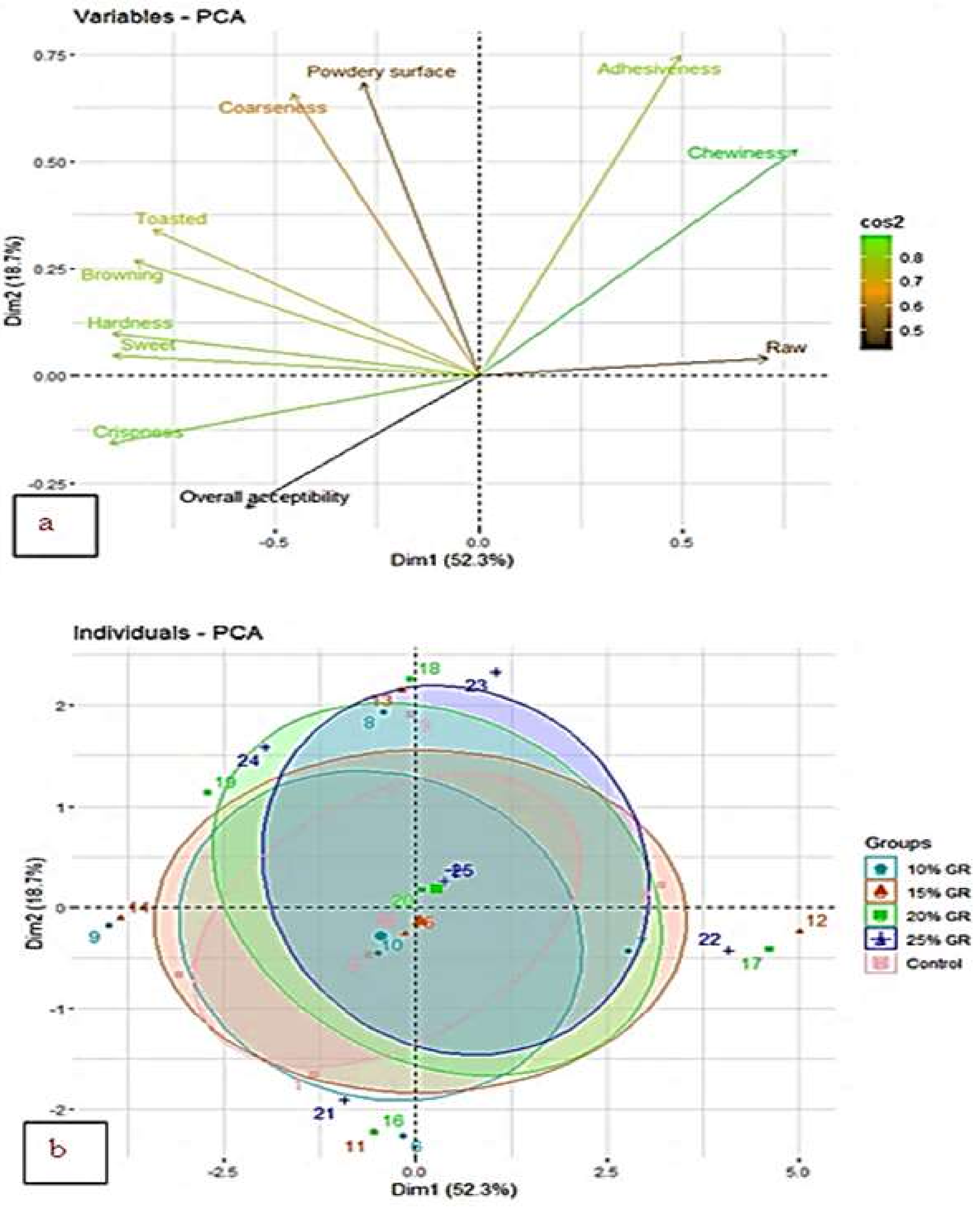


Fig. 5 Principal component analysis (a) Linear projection of loading plot of variables (b) PCA grouping of treatments with linear projection of sensory characteristics

various levels of GR are depicted in Figure 3. No variations in the overall acceptability of biscuits were observed. However, the control had a higher acceptability than the ghee-residue substituted biscuits. Among the GR substituted biscuits, 20% of the GR biscuits were more acceptable. It was also observed that with the substitution of GR for a pearl millet biscuit, the powdery surface was decreased. Furthermore, the biscuits showed no signs of rancid and foreign flavour development with the substitution of GR. Additionally, the sweetness of a product decreased, but there was no significant difference ($p<0.05$). Crispness, coarseness, adhesiveness and chewiness were found to be higher with no significant difference ($p>0.05$). The hardness of a product was increased due to fat replacement with GR which could be significantly correlated with a reduction in the tenderness of a product, leading to an increase in the hardness. Product images are shown in Figure 4.

PCA is used to characterize the effect of GR levels on pearl millet-based biscuits. All sensory scores were converted to z-score (standardized) to ensure equal influence of all sensory attributes, and subjected to multivariate analysis. On the basis of the sensory score of the panellists, PCA was applied. PCA of all attributes resulted in three principal components with Eigenvalues greater than 1 (Kaiser-Meyer-Olkin criterion) (Massart et al. 1988; Borgognone et al. 2001) explaining 85.14% of total data variation. PCA showed that the PC1, PC2 and PC3 explained 52.3%, 18.7% and 14.16% variability, respectively. Varimax rotation was applied to these retained PCs to bring them into closer alignment with the original variables (Lawless and Heymann, 2013). The Varimax rotated factor loadings, which represent correlations between PC and the original attribute measurements. The biplot (product attribute) and PCA loading plot are shown in Figure 5. Factor loadings with an absolute value greater than 0.6 represent a strong influence. PC1 was found to be positively correlated to coarseness, browning appearance, toasted and sweet flavour. PC2 has the most positive loadings for crispness, hardness and overall acceptability, and negative with raw flavour. Kayitesi et al. (2010) stated that a third principal component is needed when the first two principal components fail to differentiate. The PC3 is largely positively correlated with adhesiveness, chewiness and powdery surface appearance. Omoba et al. (2015) obtained PC1 distinguished factors for pearl millet-based biscuits like colour and visual attributes, dry and crisp texture.

Conclusions

Replacement of bakery fat with ghee residue reduced the fat level in the biscuit without affecting the other nutritional parameters. Lightness (L*) increased with fat substitution, while redness and yellowness decreased with increasing ghee residue level. However, the browning index of biscuits decreased with the addition of ghee residue which is a positive sign to reduce the toxic compounds while baking. The spread ratio decreased while the hardness of the biscuit increased with the fat replacement. The 20% GR biscuit had the highest overall acceptability among the fat-substituted biscuit components. Further, PCA reveals that adhesiveness, chewiness and raw flavour are positively correlated.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

Agrahar-Murugkar D, Jha K (2011) Influence of storage and packaging conditions on the quality of soy flour from sprouted soybean. J Food Sci Technol 48: 325-328

Agrahar-Murugkar D, Gulati P, Kotwaliwale N, Gupta C (2015) Evaluation of nutritional, textural and particle size characteristics of dough and biscuits made from composite flours containing sprouted and malted ingredients. J Food Sci Technol 52: 5129-5137

Agrawal AK, Sandey KK, Dewangan K (2017) Introspection on Mechanization of Traditional Indian Dairy Products. In: Dairy Engineering (pp. 151-174). Apple Academic Press

Arepally D, Reddy RS, Goswami TK, Datta AK (2020) Biscuit baking: A review. Lwt ;131:109726

Asrani P, Ali A, Tiwari K (2023) Millets as an alternative diet for gluten-sensitive individuals: A critical review on nutritional components, sensitivities and popularity of wheat and millets among consumers. Food Rev Int 39(6):3370-99

Bala M, Arun Kumar TV, Tushir S, Nanda SK, Gupta RK (2019) Quality protein maize based muffins: Influence of non-gluten proteins on batter and muffin characteristics. J Food Sci Technol 56:713-23.

Barak S, Mudgil D, Khatkar BS (2014) Effect of flour particle size and damaged starch on the quality of cookies. J Food Sci Technol 51:1342-8

Borgognone MG, Bussi J, Hough G (2001) Principal component analysis in sensory analysis: covariance or correlation matrix?. Food qual prefer 12: 323-326

Borawake KA, Bhosale DN (1996) Utilisation of ghee residue in preparation of nankatai type cookies and sponge cakes. Indian J Dairy Sci 49: 114- 119

Chugh B, Singh G, Kumbhar BK (2015) Studies on the optimization and stability of low-fat biscuit using carbohydrate-based fat replacers. Int J Food Prop18(7):1446-59

Chugh B, Singh G, Kumbhar BK (2013) Development of low-fat soft dough biscuits using carbohydrate-based fat replacers. Int J Food Sci: 2013

Dua S, Kumar S, Kaur S, Ganai AW, Khursheed I (2018) Chemical and sensory attributes of ghee residue burfi supplemented with corn flour. J Pharmacogn Phytochem 7(2):3818-22

Florence SP, Urooj A, Asha MR, Rajiv J (2014) Sensory, physical and nutritional qualities of cookies prepared from pearl millet (Pennisetum typhoideum). J Food Process Technol 5: 1

Gallagher E, Kenny S, Arendt EK (2005) Impact of dairy protein powders on biscuit quality. Eur Food Res Technol 221: 237-243

GM V, Singh AK (2024) Effect of Ghee Residue Powder and Pearl Millet Flour Substitution on Rheological, Textural, and Sensorial

Characteristics of Eggless Muffin. J. Food Process https://doi.org/10.1155/2024/5519265
Heymann H, Lawless HT (2013) Sensory evaluation of food: principles and practices. Springer Science and Business Media, New York
IMARC (2023) Bakery Products Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2023-2028. Market Research Report. https://www.imarcgroup.com/bakery-products-market/methodology. Accessed 10 Aug 2023
ISI (1981) IS: SP: 18 (Part V) Bakery and confectionary products. In: Handbook of Food Analysis, Bureau of Indian Standards, New Delhi
ISI (1989). IS:12711 Bakery products–Methods of analysis. Bureau of Indian Standards, New Delhi
Islam S, Yu Z, She M, Zhao Y, Ma W. (2019) Wheat gluten protein and its impacts on wheat processing quality. Front. Agric. Sci. Eng. 6(3), 279-287
Isleroglu H, Kemerli T, Sakin Yilmazer M, Guven G, Ozdestan O, Uren A, Kaymak Ertekin F (2012) Effect of steam baking on acrylamide formation and browning kinetics of cookies. J Food Sci 77: E257-E263
Janghu S, Kaushik R, Bansal V, Sharma P, Dhindwal S (2014) Physico-chemical analysis of ghee residue and conversion into confectionary food products. Indian J Dairy Sci 67(4):1-6
Kayitesi E, Duodu KG, Minnaar A, de Kock HL (2010) Sensory quality of marama/sorghum composite porridges. J Sci Food Agric 90: 2124-2132
Kulkarni DB, Sakhale BK, Chavan RF (2021) Studies on development of low gluten cookies from pearl millet and wheat flour. Food Res 5(4):114-9.
Kulthe AA, Thorat SS, Lande SB (2017) Evaluation of physical and textural properties of cookies prepared from pearl millet flour. Int J Curr Microbiol Appl Sci 6(4):692-701
Lazaridou A, Duta D, Papageorgiou M, Belc N, Biliaderis CG (2007) Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. J Food Eng 79:1033–1047
Leiva-Valenzuela GA, Quilaqueo M, Lagos D, Estay D, Pedreschi F (2018) Effect of formulation and baking conditions on the structure and development of non-enzymatic browning in biscuit models using images. J Food Sci Technol 55: 1234-1243
Manwaring HR, Bligh HF, Yadav R (2016) The challenges and opportunities associated with biofortification of pearl millet (*Pennisetum glaucum*) with elevated levels of grain iron and zinc. Front. Plant Sci. 7:237292.
Mariotti Celis MS, Zúñiga RN, Cortés P, Pedreschi F (2017) A kinetic study of furan formation in wheat flour based model systems during frying. J Food Sci 82: 232-239
Massart DL, Vandeginste BGM, Deming SN, Michotte Y, Kaufman L (1988) Principal components and factor analysis. In: Chemometrics: A textbook 2: pp 339-370
Mehra A, Singh U (2017) Sensory and nutritional evaluation of biscuits prepared from pearl millet (bajra). Int J Food Sci. Nutr 2:47-9
Moriano ME, Cappa C, Alamprese C (2018) Reduced-fat soft-dough biscuits: Multivariate effects of polydextrose and resistant starch on dough rheology and biscuit quality. J Cereal Sci 81: 171-178
Mundt S, Wedzicha BL (2007) A kinetic model for browning in the baking of biscuits: Effects of water activity and temperature. Lwt-Food Sci Technol 40: 1078-1082
Omoba OS, Taylor JR, de Kock HL (2015) Sensory and nutritive profiles of biscuits from whole grain sorghum and pearl millet plus soya flour with and without sourdough fermentation. Int J Food Sci Technol 50: 2554-2561
Pauly A, Pareyt B, Lambrecht MA, Fierens E, Delcour JA (2013) Flour from wheat cultivars of varying hardness produces semi-sweet biscuits with varying textural and structural properties. LWT - Food Sci 53(2):452-457
Purlis E (2010). Browning development in bakery products–A review. J Food Eng, 99: 239-249
Raju PN, Rao KH, Devi NL (2007) Preparation and evaluation of high protein biscuits containing whey protein concentrate J Food Sci Technol 44: 532-535
Ranjan R, Chauhan AK, Kumari SS, Dubey RP (2020) Nutritive value of ghee residue incorporated bakery product. Indian J Dairy Sci 73: 51-56
Sanni SA, Adebowale ARA, Olayiwola IO Maziya-Dixon B (2008) Chemical composition and pasting properties of iron fortified maize flour. J Food Agric Environ 6: 172-17
Singh N, Rani R (2019) Utilization of dairy by-products for development of dairy and food products. In: Recent Technologies in Dairy Science, Today & Tomorrow's Printers and Publishers, New Delhi (pp 511-529).
Sudha ML, Srivastava AK, Vetrimani R, Leelavathi K (2007) Fat replacement in soft dough biscuits: Its implications on dough rheology and biscuit quality. J Food Eng 80: 922-930
Tyagi SK, Manikantan MR, Oberoi HS, Kaur G (2007) Effect of mustard flour incorporation on nutritional, textural and organoleptic characteristics of biscuits. J Food Eng 80: 1043-1050
Varma BB, Narender Raju P (2008) Ghee residue: Processing, properties and utilization. course compendium on "Technological advances in the utilization of dairy by-products". Centre of Advanced Studies in Dairy Technology, National Dairy Research Institute, Karnal
Wani AD, Prasad W, Khamrui K, Jamb S (2022) A review on quality attributes and utilization of ghee residue, an under-utilized dairy by-product. Future Foods ;5:100131