Analyzing the effect of germination on nutritional characteristics of kodo millet flour and its role in rusk development

ABSTRACT

Millets, the underutilized groups of cereal grains are considered as rich source of energy, carbohydrate and protein. Due to the presence of vitamins, minerals, essential fatty acids, phytochemicals and antioxidants that can help to eradicate several nutritional deficiency diseases, they are now termed as 'nutri-cereals' They contain appreciable quantities of phytochemicals such as phenolic acids, flavonoids, catechins, phytic acid and phytosterols. Owing to their important contribution in food security and potential health benefits, millet grains are now main topic of research for food scientists. This study thus aimed to develop kodo millet flour (KMF) via varying germination time (0h, 24h, 48h, and 72h) of kodo millet and preparing a bakery product (rusk) using the optimized KMF at varying concentrations of 0, 20, 30 and 50%. The germinated KMF were subjected to physiological studies, namely germination loss and germination efficiency. Optimum germination time was observed to be 48 h due to its high germination efficiency and a significantly lower germination loss as compared to 72 h of germination. Proximate analysis of KMF helped determine the increase in protein and fibre content of the germinated flour and a decreased ash, fat and moisture content. The significant changes ($p \leq 0.05$) observed in all the analyses, helped determine the effect of different germination periods on various properties of dehusked kodo millet, and further optimize a particular germination time for better quality flour which would be used to form rusk. The results of this study thus suggested that germination of kodo millet could be effectively used to prepare kodo millet flour and further use it to prepare various baked products having good consumer acceptability.

Keywords: Millet, Germination loss, Germination efficiency, Kodo millet, Rusk

1. INTRODUCTION

Millets, a group of small-seeded grains cultivated globally for centuries, have long been celebrated for their nutritional density and resilience in diverse agricultural conditions. There are several types of millets, including pearl millet, sorghum, finger millet, foxtail millet, kodo millet and more [1]. These grains are highly nutritious, gluten-free, and resilient crops, offering a range of health benefits. However, it is their exceptional fibre content that has garnered particular attention in the context of modern dietary recommendations [2]. Unlike refined grains, which have their fibre-rich parts removed during processing, millets keep their natural fibre. This makes millets a good option for adding fibre to bakery products [3]. Dietary fibre plays a pivotal role in maintaining digestive health, regulating blood sugar levels, and reducing the risk of chronic diseases such as heart disease and diabetes [4]. However, conventional bakery products often fall short in providing adequate fiber content, primarily due to the predominant use of refined flours. To fill this gap in nutrition, we need creative ways to use the healthy aspects of different grains, such as millets [5]. One such promising choice is kodo millet (*Paspalum scrobiculatum*), celebrated for its exceptional nutritional profile and versatile culinary applications [6]. Kodo millet is rich in protein (8.0-8.3g/100g), dietary fiber (6.3g/100g), vitamins, and minerals (2.6mg/100g), making it a promising ally in fighting malnutrition and promoting dietary variety among diverse populations [7]. Additionally, it contains significant quantities of vital minerals like calcium (32.3/100g), magnesium (110mg/100g), iron (3.7mg/100g), zinc (1.6 mg/100g), manganese (1.10mg/100g), and B complex vitamins (1.6-1.9mg/100g), reinforcing its status as a nutritional powerhouse [8]. The high percentage of non-starch polysaccharides and dietary fibre in kodo millets aids in weight management and makes them an excellent dietary choice for individuals with diabetes, as they facilitate slow glucose release [9]. Moreover, kodo millets serve as an excellent source of prebiotics, fostering the growth of beneficial gut bacteria such as *Lactobacillus acidophilus*, *rhamnosus GG*, A*ctinobacteria*, and *Bifido* species. The fibre fraction of millets allows for the binding of antioxidants, ensuring their gradual release in the gut during digestion, thereby maximizing their bioavailability and enhancing their protective effects against non-communicable diseases [10].

Few studies have reported the effect of replacing traditional flours with kodo millet flour on the sensory attributes, nutritional composition, and overall acceptability of baked products. Additionally, different processing techniques and formulation strategies were also examined to optimize the incorporation of kodo millet while maintaining desirable texture and taste [6]. In this context, the incorporation of germinated kodo millet flour represents a novel strategy to develop fibre-enriched rusks that not only meet consumer preferences but also fulfill nutritional requirements. Germination, a natural process that enhances the nutritional quality of grains, involves the activation of enzymes and the breakdown of complex carbohydrates into simpler, more digestible forms [11]. Germination has been reported in several studies to be successful in controlling the lipid profile of various millet flour, thereby providing for an alternative for dietary diversification [12]. Germinated kodo millet flour, rich in bioactive compounds and nutrients, serves as a potent ingredient for fortifying bakery products with dietary fiber, proteins, vitamins, and minerals. By optimizing the integration of germinated kodo millet flour into rusk formulations, it is possible to create a functional food product that offers enhanced nutritional benefits and promotes overall well-being [6]. Lots of studies have been done on its processing techniques such as germination, malting, fermentation, dehulling and roasting. These processes help in improving the nutritional sensory and palatability quality of kodo millets along with its anti-nutritional quality which inhibits the absorption of some other nutrients in the bod [13].

The objectives of this research thus can be detailed as germination of kodo millet at varying time duration to obtain flour rich in nutritive value, followed by its application to produce a fortified rusk, that is a widely eaten bakery product by a large population of the world. The germinated flour as well as the fortified rusk were further subjected to nutritional and qualitative evaluation.

2. MATERIAL AND METHODS

2.1 Raw materials

Fresh, dehusked kodo millet of variety, Kherapa was procured from the local market of Dodhpur, Aligarh. Wheat flour (soft), sugar, ghee, skimmed milk powder, salt, and yeast were also purchased from the local market of Aligarh, Uttar Pradesh. Deionized water was employed for dough preparation and product analysis.

2.2 Processing of Kodo Millet Flour (KMF)

Dehusked kodo millets were cleaned under running tap water to remove foreign materials and unfit grains. They were then soaked overnight (10h) at room temperature. The subsequent swelled grains were subjected to varying periods of germination (24h, 48h, 72h). The soaked grains were divided into 4 lots, first lot was not subjected to germination and was dried and grinded to obtain flour and termed as T1 (0h germination), while the rest of the three lots each were transferred into wet muslin clothes, kept in netted baskets. These baskets were placed in a dark and dry space at room temperature, where regular sprinkling of water (every 2h) was done to provide proper humidity for the germination process. Germination process was halted for the different lots after 24h, 48h and 72h and subjected to drying as per the method described by Kumar et al. [14]. With slight modifications. Drying was done at 65°C for 2h in a tray dryer followed by grinding into fine flour. Obtained flour were packed in HDPE bags and termed as T2, T3 and T4 for flour obtained after 24h, 48h, and 72h of germination respectively.

2.3 Physiological analysis of Kodo millet Flour (KMF)

Germination or malting loss measures the weight loss that occurred in the grains during the germination process. It was calculated by the following formula [15]:

$$Total\ Germaination\ /Malting\ loss\ (\%) = \frac{W_o - W_g}{W_o} \times 100$$

where, W_o - weight of grains before germination, and W_g - weight of grains after germination

Germination efficiency was calculated according to the formula used by Anjum et al. [16], wherein total number of seeds (B) and number of germinated seeds (A) were counted manually.

$$Germination\ Efficiency\ (\%) = \frac{A}{B} \times 100$$

2.4 Proximate and color analysis of Kodo Millet Flour (KMF)

Moisture content of the flour samples was determined by HE53 Mettler Toledo Halogen Moisture Analyser. Nutrient composition of the different flours used and cookies formulated were determined by proximate analysis of ash, fat, fibre and protein using the method prescribed by AOAC [17]. Total Carbohydrate content of the flour samples was calculated by the difference among the other constituents in the sample (protein, fat, moisture, fibre, ash) and the total weight of the sample. Energy values were calculated using the Atwater Factors.

Color differences among the different flour samples were determined by measuring the L* (lightness), a* (green-red) and b* (blue-yellow) values with a Hunter Lab colorimeter (CR

300, Konica Minolta, Japan). The device was calibrated with black and white tiles before analyzing the samples for color.

2.5 Optimization and Development of Rusk

Various ingredients in predetermined ratio were taken to form rusk from the optimized germinated KMF. Dough was prepared by varying the ratio of wheat flour (WF) and optimized germinated kodo millet flour (KMF). Incorporation of KMF in the various rusk samples ranged from 0% in S1, 20% in S2, 30% in S3, and 50% in S4. It was noted after preliminary experiments that any higher substitution of KMF (>50%) in the dough, resulted in bad texture of the formed bread, crumbling instantly thus proving to be a futile attempt at making rusk. Other ingredients included sugar, yeast, ghee, milk powder and small amount of salt.

Flour was gradually added to the creamy mixture prepared from ghee and sugar. Yeast and rest of the ingredients were then added to form a light sticky dough. Water was added cautiously to prevent over sticking of dough. Dough was kept in BOD incubator at 36.7°C (1 h) to allow yeast fermentation. Soft fermented dough was then subjected to kneading, followed by moulding. Moulded dough was placed in specifically designed and buttered baking trays and kept in BOD for proofing (2h). Baking was done in two steps: first step involved baking in preheated oven (200°C) for 25 min. at 180°C, and second step involved cooling of baked bread, slicing and re-baking for 15 min. at 150°C to obtain a crispy rusk. Developed rusks were packed in LDPE packets and stored in a dry place at room temperature.

2.6 Proximate, color and sensory analysis of Rusk

The proximate and color (L*, a*, and b*) values of the developed rusk were analysed as discussed earlier in the section 2.4.

Sensory analysis of the rusk samples was conducted in the product development laboratory of Department of Post-Harvest Engineering and Technology, Aligarh Muslim University, India. Trained and semi-trained panelists comprising of researchers, students, and faculty members of the department evaluated all the samples for acceptability using a nine-point

Hedonic scale, where 1 corresponds to most disliked attribute and 9 corresponds to most liked attribute. Rusk samples were analyzed for appearance, texture, taste, flavor, and overall acceptability. Overall acceptability of samples was calculated from the average of all the above sensory parameters.

2.7 Statistical Analysis

The results of average of triplicates were expressed as mean ± standard deviations. Data of various analyses for germinated KMF, and rusk prepared from optimized germinated KMF were analyzed using Duncan multiple comparison test ($p \leq 0.05$) using the IBM SPSS Statistics 20 and presented as significant difference among the various samples.

3. RESULTS AND DISCUSSION

3.1 Germination Loss & Germination Efficiency

Germination results in increased activity of hydrolytic enzymes and breaks down major compounds such as starch, fibre and protein [18]. It is known to improve the nutritive value of cereals and legumes. Germination has also been found to decrease the levels of antinutrients present in cereals and maximizes the levels of some of the utilizable nutrients [19, 20].

Germination loss was observed to increase as the germination time was increased. A significant increase ($p \leq .05$) for T1 from 4.34 ± 0.47% to 5.14 ± 0.69% for T2 was observed when the germination was allowed for 24h (Fig. 1). Further the sample T3 exhibited another sharp significant increase ($p \leq .05$) from 5.34 ± 0.19% to 8.10 ± 0.12% for T4 when the germination time was increased to 72 h (Fig. 1). Germination causes increased metabolic activity resulting in partial degradation of carbohydrates, and eventually causing loss of weight [14]. Loss of water-soluble minerals and vitamins may also have contributed to the observed germination loss [21]. Hence, increased germination loss was observed on increasing the germination time.

Meanwhile, germination efficiency also exhibited significant increase ($p \leq .05$) with the increase in germination time. Average values for the germination efficiency for the variously germinated kodo millet samples were 0.83 ± 1.44%, 19.25 ± 1.53%, 90.16 ± 1.06% and

98.30 ± 0.82% for T1, T2, T3, and T4 respectively. Higher germination efficiency (> 90%) was observed for millet samples germinated for longer duration, i.e., 48 h and 72 h, however these samples also exhibited increased germination loss. Optimum germination time was observed to be 48 h due to its high germination efficiency and a significantly lower germination loss as compared to 72 h of germination.

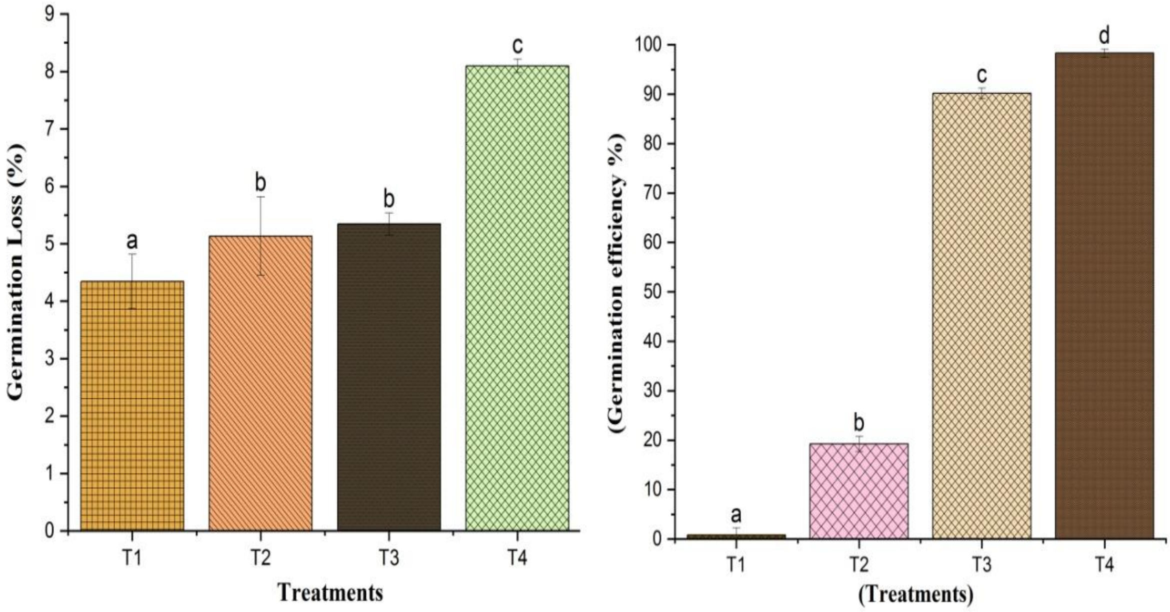

Fig. 1. Physiological analysis of kodo millet flour for (a) Germination Loss; and (b) Germination Efficiency. T1 – 0 h, T2 – 24 h, T3 – 48 h, T4 – 72 h (germination time).

3.2 Proximate compositions of Kodo millet flour (KMF)

Proximate analysis of the different kodo millet flour obtained after milling of the germinated millet presented significant variations as shown in Table 1. Ash content of the different flour samples observed an initial significant increase ($p \leq .05$) with the increase in germination time till 48 h, thereby indicating an increase in the mineral content of the flour. Similar findings have been reported for germinated finger, foxtail and pearl millet flours [22]. Further increase in germination period, beyond 48 h, showed a decline in ash content which may have occurred due to leaching of minerals during steeping and washing or due to use of some minerals for initiation of sprouting [14] as has earlier been reported for finger millet flour after 96 h of germination [21].

At the same time the moisture content of the different flour samples decreased significantly (*p* ≤ *.05*) with the increase in germination time. Similar findings have been reported for germinated quinoa and kiwicha [23]. Germination process might have resulted in the water absorption by the grains.

Significant reductions (*p* ≤ *.05*) in the fat content of the different kodo millet flour samples subjected to varying germination times with an increase in the germination period was observed. The average values decreased from 4.05g/100g prior germination to 2.98g/100g after 72 h of germination. Similar findings have been reported for finger and pearl millet with considerable reduction in fat content after germination [24]. Pilco-Quesada et al. [23] also had similar observations for germinated quinoa and kiwicha. As fat is a stored form of energy, it probably got utilized during germination, thereby resulting in its decline with an increase in the germination period. Moreover, the activity of several enzymes might also have affected the fat content. Therefore, the lowered fat content of germinated flour might increase the shelf life of the flour as the enzymes produced during germination may contribute to reducing rancidity.

A significant increase (*p* ≤ *.05*) in protein content of the different flour samples was observed with an increase in germination period. The protein content which was earlier 10.41g/100g prior germination process increased to 12.53g/100g after 72 h of germination. The protein content of finger millet flour increases as the germination time increased due to the activity of the protease, an increase that degrades peptides into amino acids [11]. Germinated few elite finger millet varieties, pearl millet [21, 25] and common buckwheat, foxtail and proso millet [14] also reported similar increase in protein content after germination. Similar observation was also reported by Pilco-Quesada et al. [23] for germinated quinoa and kiwicha.

Germination above 24 h resulted in a significant increase (*p* ≤ *.05*) in crude fibre. The crude fibre increased from an initial 8.05% to 9.95% after 72 h of germination. Similar findings have been reported in finger and pearl millet [24, 25] and in germinated buckwheat, foxtail and proso millet [26].

Adebiyi et al. [27] reported increase in fibre content as a result of the breakdown of starch and the creation of structural elements like hemicellulose and cellulose during germination. Similar observation was earlier found in a study of various varieties of pearl millet germination, wherein slight increase in crude fibre was resultant of formation of new cell wall structure [28]. Sprouting also results in development of new cell walls [29]. Parts of roots and shoots that remain adhered to millet grains after deculming may also contribute to the increase in the crude fibre content.

A significant increase ($p \leq .05$) of carbohydrate content was observed after 48 h of germination from 61.60g/100g to 62.98 g/100g. The variation in carbohydrate content could be due to the rise and reduction of other food components such as moisture, fat, protein, ash and crude fibre during germination [30]. Some studies have observed a decrease in carbohydrate content on prolonged germination this may have happened due to the utilisation of carbohydrates as an energy source to start the germination process [31] and a rise in α -amylase activity may also be the reason for the decrease in carbohydrate content [32].

3.3 Color characteristics of Kodo millet flour (KMF)

The different color parameters, lightness (L*), redness (a*) and yellowness (b*) varied with the increase in germination time of kodo millet (Table 2). L* values exhibited a significant increase ($p \leq .05$) from 61.44±1.74 to 67.18±0.07 after 72 h of germination. The increase in lightness could be attributed to the removal of bran layers during soaking and germination [21]. The result of this study was in accordance with the findings of Nefale & Mashau [33], that conferred increased sprouting of grains during germination as the reason behind increased lightness of the finger millet flour.

On the contrary, redness values (a*) exhibited a significant decrease ($p \leq .05$) with an increase in germination time. The redness value for ungerminated millet flour was 2.17±0.20 which reduced to 1.53±0.03 after 72 h of germination. Despite indicating no significant pattern in the colorimetric values of germinated finger millet flour, a distinctive decrease in all germinated samples of finger millet flour was observed in comparison to the ungerminated flour [34]. Similar findings have been reported by Nefale & Mashau, [33] and Yenasew et al., [21].

Similarly, yellowness (b*) values also suffered significant reduction ($p \leq .05$) by the end of germination period with a slight increase during low germination periods. Nefale & Mashau [33] also reported similar increase in b* values with increase in germination period. In this study, the ungerminated sample exhibited b* values of 9.72±0.74 that had reduced to 8.58±0.07 after 72 h of germination. Similar observation has been reported for other millet varieties [21, 34].

3.4 Optimization of Kodo Millet Flour (KMF)

To explore the possibility of development of a bakery product, rusk in this study, the variously germinated kodo millet flour (KMF) were subjected to optimization to obtain one such flour variety that could be partially substituted with wheat flour to prepare bread and rusk. The optimization process involved study of all the proximate properties, color variations and germination loss and efficiency of the variously germinated flour. Germination loss was significantly ($p \leq .05$) high after 72 h of germination as observed in Fig. 1. Interestingly, negligible change in germination loss was observed at 24 h and 48 h of germination period. However, after 48 h of germination a significant increase was observed providing a negative observation of extended germination period. Simultaneously, germination efficiency was also observed to increase with increase in germination time, thereby providing a positive outcome of the process as germination has been reported to improve the nutritional quality of the grains [11] by activating enzymes and formation of simpler and digestible forms of sugars, paving way for production of more diverse forms of food for population suffering from gastrointestinal problems. This was evident from the significant increase in fibre content and simultaneous decrease in carbohydrate and fat content of the germinated kodo millet flour samples. Therefore, after examining the results of this study, it was concluded that germination period of 48 h was optimum and flour obtained from the same could be utilized further for product development.

3.5 Proximate compositions of Rusk

Optimized germinated kodo millet flour was used in varying substitutions of 0 %, 20%, 30% and 50% with wheat flour to develop kodo millet incorporated rusk. Proximate analysis performed for the various rusk samples, namely S1, S2, S3 and S4 yielded significant differences for ash, moisture, fat, fibre, protein and carbohydrate content (Table 1). Ash content was observed to increase significantly ($p \leq .05$) with an increase in the substitution of KMF for the rusk samples. Ash content was lowest (1.28±0.15) for S1 having absence of KMF, while highest (2.06±0.09) for S4 having maximum substitution of KMF of 50%. Since kodo millet is high in mineral content as compared to wheat this variation gets reflected in the ash content of the final product. The moisture content also decreased significantly ($p \leq .05$) with an increase in the substitution of kodo millet in the rusk. Highest moisture content was observed for S1 with 1.89±0.06% prepared with 100% WF and lowest for S4 with 1.05±0.06% prepared with 50% wheat and kodo millet flour. Since among the rusk samples, the former had absence of KMF while the latter had 50% concentration of KMF, the moisture content of the final product varied accordingly. Similar observation was reported by Sindhu and Radhai, [35] during development of composite millet flour incorporated rusk.

An increasing trend was observed for the crude fat, fibre and protein content. A significant increase ($p \leq .05$) in fat content from 12.94±0.10 to 14.45±0.14 for S1 to S4 was observed with the increased substitution of KMF. Similarly, for fibre content the significant increase ($p \leq .05$) was from 1.73±0.04 to 5.32±0.02 and for protein content, it was from 8.63±0.07 to 8.94±0.01 for S1 to S4 with the increased substitution of KMF. The results were in accordance to previous studies, where kodo millet is reported to be rich in fibre and protein content [36, 37] which was also evident from this study. Germination of kodo millet further increased the protein and fibre content, thus making it ideal for preparing fibre-rich food products [38, 39]. Wheat flour is known to lack in fibre content and hence not preferred to make food products for the population suffering from lifestyle disease such as hypertension, diabetes, cardiovascular diseases, etc. Further, some other ingredients like milk powder might have also contributed to the protein content of each sample.

The carbohydrate content of the rusk decreased significantly ($p \le .05$) from 73.53±0.17 to 68.17±0.16 for sample S1 to S4 with an increase in the percentage of kodo millet. This decrease may be consequent to the increase in fat, fibre and protein content with an increase in the proportion of kodo millet. Meanwhile, the energy value still cannot set a sequence with the increase in kodo millet. The highest calorific value of 446.831 kcal was observed in S2 which had 20% substitution of wheat flour with KMF. Whereas the lowest calorific value of 438.322 kcal was observed in S4 with the highest substitution of 50% of KMF. The variance in energy value may have been due to the variations observed in the value of crude fibre, crude protein and carbohydrate.

3.6 Color characteristics of rusk

The different color parameters, lightness (L*), redness (a*) and yellowness (b*) varied with the increased substitution of wheat flour with kodo millet flour (Table 2). L* values exhibited a significant decrease ($p \le .05$) from 47.49±4.14 in S1 to 38.45±3.06 in S4. This decrease may be attributed to the decrease in the wheat flour content with the increase substitution of KMF. Similar findings have been reported by Gupta et al. [40] during the preparation of high fibre rusks by the substitution of wheat flour with barley flour. Similar decrease in lightness values was also observed during preparation of wheat flour rusks with debittered fenugreek flour [41]. Similarly, redness values (a*) also exhibited a significant decrease ($p \le .05$) with an increase in the substitution of KMF. The redness value for S1 was 14.77±1.22 (0% KMF) which reduced to 8.94±1.75 for S4 (50% KMF). Yellowness (b*) values also suffered significant reduction ($p \le .05$) with increased KMF substitution. The values for S1 (0% KMF) were 35.40±1.58 which decreased to 23.18±2.02 for S4 (50% KMF).

Table 1. Proximate compositions of KMF and Rusk

Parameters (% d.b.)	Kodo Millet Flour (KMF)				Rusk			
	T1	T2	T3	T4	S1	S2	S3	S4
Ash	0.99±0.03[a]	1.96±0.02[b]	2.03±0.04[b]	1.97±0.02[b]	1.28±0.15[a]	1.56±0.03[b]	1.67±0.08[b]	2.06±0.09[c]
Moisture	14.90±0.70[a]	13.50±0.65[b]	10.25±0.47[c]	10.09±0.03[c]	1.89±0.06[a]	1.62±0.07[b]	1.30±0.07[c]	1.05±0.06[d]
Crude Fat	4.05±0.07[a]	3.94±0.05[b]	3.43±0.05[c]	2.98±0.04[d]	12.94±0.10[a]	13.56±0.11[b]	13.83±0.10[c]	14.45±0.14[d]
Crude Fibre	8.05±0.08[a]	8.85±0.07[b]	9.73±0.26[c]	9.95±0.15[c]	1.73±0.04[a]	3.15±0.01[b]	3.76±0.03[c]	5.32±0.02[d]
Crude Protein	10.41±0.30[a]	10.99±0.13[b]	11.57±0.50[c]	12.53±0.18[d]	8.63±0.07[a]	8.75±0.01[b]	8.84±0.03[c]	8.94±0.01[d]
Carbohydrate	61.60±0.05[a]	60.77±0.64[a]	62.98±0.41[b]	62.48±0.30[b]	73.53±0.17[a]	72.46±1.89[b]	70.58±0.12[c]	68.17±0.16[c]
Energy (kcal)	324.51±2.90[ab]	322.49±2.85[a]	329.10±0.99[b]	326.75±0.63[ab]	445.1±1.33[a]	446.83±0.62[a]	442.17±0.63[ab]	438.32±0.89[b]

T1 – 0 h, T2 – 24 h, T3 – 48 h, T4 – 72 h (germination time). S1 – 0%, S2 – 20%, S3 – 30%, S4 – 50% (optimized KMF concentration)

Values are expressed as mean ± standard deviation, where the superscript alphabets represent statistical differences ($p \leq .05$) between the various samples of KMF and rusk according to ANOVA Duncan's Post-hoc test.

Table 2. Color characteristics of KMF and Rusk

Color parameters	Kodo Millet Flour (KMF)				Rusk			
	T1	**T2**	**T3**	**T4**	**S1**	**S2**	**S3**	**S4**
L*	61.44±1.74^{a}	63.76±1.03^{b}	63.30±4.02^{b}	67.18±0.07^{c}	47.49±4.14^{c}	36.60±6.59^{a}	36.56±7.52^{a}	38.45±3.06^{b}
a*	2.17±0.20^{c}	1.96±0.07^{b}	1.98±0.07^{b}	1.53±0.03^{a}	14.77±1.22^{c}	12.60±1.31^{b}	11.57±2.99^{b}	8.94±1.75^{a}
b*	9.72±0.74^{b}	10.16±0.14^{bc}	10.72±0.07^{c}	8.58±0.07^{a}	35.40±1.58^{c}	27.06±3.47^{b}	25.09±0.63^{b}	23.18±2.02^{a}

T1 – 0 h, T2 – 24 h, T3 – 48 h, T4 – 72 h (germination time). S1 – 0%, S2 – 20%, S3 – 30%, S4 – 50% (optimized KMF concentration)

Values are expressed as mean ± standard deviation, where the superscript alphabets represent statistical differences ($p \leq .05$) between the various samples of KMF and rusk according to ANOVA Duncan's Post-hoc test.

3.7 Sensory Evaluation of Kodo millet incorporated Rusk

Sensory analysis scores for the prepared rusk has been presented in Fig. 2. Analysis was made in terms of appearance, texture, taste, flavour, and overall acceptability for all the four samples of the developed rusks. The result of the sensory analysis showed the highest rating for the texture for the sample S2, prepared with 20% incorporation of KMF as compared to all other samples. Appearance rating was done on the basis of color of rusk samples and S2 again exhibited high scores when compared to all the other samples. The taste and flavour also presented similar results and found to be more appealing when compared to all the other samples. Therefore, rusk prepared with 20% incorporation of KMF presented highest overall acceptance by the panelists.

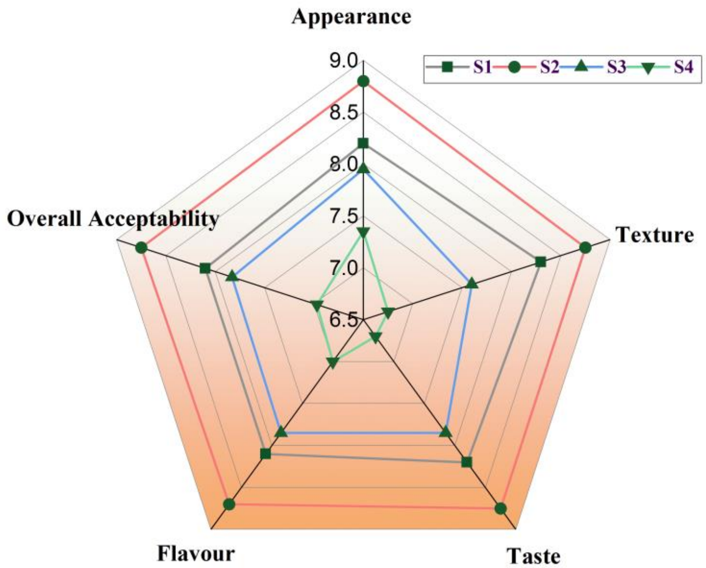

Fig. 2. Sensory Evaluation of KMF incorporated Rusk

4. CONCLUSION

In accordance to previous studies, this work further established that germination helps in increasing the protein and fibre content of kodo millet flour while decreasing the ash, fat and moisture content of the same. Reduced fat content in the germinated kodo millet flour, thus demonstrated the potential of germination in controlling the lipid content in the flour and at the same time providing with millet flour with improved protein and fibre content. These results indicated the benefits of using germinated millet flour which could further be used to prepare various food products.

The optimized germinated kodo millet flour was successfully used to develop acceptable rusks with good sensorial attributes by replacing wheat flour with kodo millet flour. With the increased substitution of wheat flour with kodo millet flour, fibre, protein and ash content was found to increase. Hence, high fibre content of germinated kodo millet flour provided as a suitable option for rusk preparation. It was interesting to note that higher substitution of millet flour led to crumbling of the formed product, however to maintain texture of the formed bread and rusk, additional ingredients may be added that would help bind the final product. Therefore, considering the potential health benefits of millets, their consumption in day-to-day life could be boosted by increasing the usage of germinated millet flour. It is imperative to increase the demand for millets among people by prioritizing our focus towards millet processing efforts, aiming to stimulate demand by enhancing the value of millet-based processed foods. This could be attained through diversified processing technologies such as, germination, fermentation, roasting, drying, etc.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

Here is the Definitions section. This is an optional section.

Term: Definition for the term

HDPE : High density polyethylene
LDPE : Low density polyethylene
SPSS : Statistical Package for Social Sciences
ANOVA : Analysis of Variance
d.b. : dry basis