

Functional Properties of Finger Millet and Barnyard Millet Flours and Flour Blends

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Abstract: Millets are highly nutritious small seeded grasses, which contain high amount of protein, fibre, essential amino acids and other micro nutrients. Finger millet and barnyard millet are the minor millets with superior nutritional qualities and antioxidant properties. Though incorporation of these millet flours can enhance the nutritional value of conventional cereal flours, the functional properties of the flour can greatly be affected due to varied protein and fibre content. Finger millet variety PRM-15 and barnyard millet variety PRJ-1 were separately incorporated in refined wheat flour in different blends viz. 70:30, 60:40, 50:50 and 40:60; (Refined wheat flour : millet flour) and functional properties (viz. water absorption, fat absorption, sedimentation value, emulsion activity, emulsion stability, dough raising capacity and gluten content of these blends were analyzed. Water absorption capacity and fat absorption capacity of barnyard millet flour (158.63 ml and 146.67 ml, respectively) and finger millet flour (140.77 ml and 141.47 ml, respectively) were significantly higher than the refined wheat flour (131.93 ml and 118.10 ml, respectively). An increasing trend in water absorption and fat absorption was observed with the millet flour incorporation. Refined wheat flour had significantly higher values for other functional properties viz. sedimentation value, emulsion activity, emulsion stability, dough raising capacity and gluten content as compared to both millet flours and with incorporation of millet flours in different blends showed gradual decreasing trend.

Keywords: finger millet, barnyard millet, refined wheat flour, blends, functional properties

1. Introduction

Functional properties are the essential physico-chemical properties that show the complex interaction between the composition, structure, molecular conformation and physico-chemical properties of food components along with the nature of environment in which these are associated and measured (Kinsella, 1976). Functional characteristics are required to evaluate and possibly help to predict how new proteins, fat, fibre and carbohydrates behave in specific systems as well as demonstrate whether or not such protein can be used to stimulate or replace conventional protein (Mattil, 1971). The functional properties viz. water absorption capacity, fat absorption capacity, sedimentation value, emulsion activity and stability, dough raising capacity and gluten content of flour are essential determinants of baking quality of the product. The sensory attributes, textural properties and shelf life of the bread and similar products are greatly affected by these properties.

Millets are small seeded grasses which are highly nutritious and are even superior to staple cereals like rice and wheat in certain constituents. These are an important source of nutrients like niacin, magnesium, phosphorus, manganese, iron and potassium. They contain high amounts of protein, fibre, essential amino acid methionine, lecithin, and vitamin E. One of the characteristic grain composition features of millet is their high ash content. Millets contain large quantities of phenolics and other compound which prevent deterioration of human health (Yenagi and Mannurmath, 2013). Finger millet (*Eleusine coracana*) and barnyard millet (*Echinochloa frumentacea*) come under the category of minor millets with superior nutritional quality and antioxidant activity. Incorporation of these millets in the conventionally used refined wheat flour can improve the

nutritional quality of the bread and similar products, besides the changes in the functional properties of the flour. The present study therefore has been undertaken with the objective to prepare different blends of finger millet and barnyard millet flour separately with refined wheat flour and to compare their functional properties.

2. Materials and Methods

The study was conducted in the Department of Foods and Nutrition, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Finger millet (*Eleusine coracana*) variety PRM-15 and barnyard millet (*Echinochloa frumentacea*) variety PRJ-1 were procured from Pauri (Uttarakhand). Finger millet and barnyard millet grains were washed, cleaned, dried in hot air oven at 60°C for 3 hours, followed by pearling and milling. Millet flour was used for preparation of different flour blends with refined wheat flour viz. 30:70, 40:60, 50:50, and 60:40 (millet flour: refined wheat flour).

Water absorption capacity of flour was analyzed by using method given by Lin *et al.* (1974). One g of sample was mixed with 10 ml of water in a 35 ml centrifuge tube and agitated for 1 min to disperse the sample. The suspension was shaken for 30 min at 24°C, and centrifuged at 3700 rpm for 25 min. The water retained by the grains was computed as water absorbed, i.e., ml water absorbed per gram of sample.

$$\text{Water absorption(ml/g)} = \frac{\text{Volume of water absorbed (ml)} \times 100}{\text{Weight of sample (g)}}$$

Fat absorption was measured by a modification of the method used by Lin *et al.* (1974). Peanut oil (3ml) was

added to 500 mg of sample in centrifuge tube, stirred for 1 min using magnetic stirrer to disperse the sample. After holding at 24°C for 30 min, the sample was centrifuged at 3700 rpm for 25 min. The oil retained in the sample was expressed as fat absorbed in ml of oil per g of sample.

$$\text{Fat absorption (ml/g)} = \frac{\text{Volume of oil absorbed (ml)} \times 100}{\text{Weight of sample (g)}}$$

Sedimentation value was determined by following AACC (1969) procedure. Fifty ml of water containing 4 ppm bromophenol blue was added in a flour sample (3.2 g) and mixed thoroughly. Twenty five ml of lactic acid reagent was added to flour suspension and mixed again for 5 min. The cylinder was allowed to stand in upright position for 5 min. After that, volume of sediment in the cylinder was noted in ml.

$$\text{Emulsifying stability (\%)} = \frac{\text{Height of emulsified layer after heating} \times 100}{\text{Height of total contents in the tube}}$$

The dough raising capacity was measured by using the method of Hamad and Al - Eid (2005) with slight modification. A 2.5g yeast was dissolved in lukewarm water (45ml) having 40°C temperature. Thirty five g flour sample was taken in a beaker and 1g sugar was added to it and then mixed with the yeast suspension. This mass was made into smooth batter and transferred to a 250 ml graduated cylinder and base volume of the batter was noted down. The rise in the level of dough was noted after one hour.

Calculation

$$\text{Dough raising capacity (\%)} = \frac{(B - A)}{A} \times 100$$

Where, A = volume of the dough before fermentation.
B = volume of dough after one hour fermentation.

Gluten content was determined following AOAC (2000) procedure. Twenty five gram flour was kneaded in a bowl and a dough ball was made. The dough ball was placed in water at room temperature for one hour. The dough was then kneaded with fingers gently in a thin stream of tap water until all the starch and soluble matter were removed. The gluten thus obtained by washing was pressed as dry as possible between hands, made into a ball and weighed. The gluten was then dried in the dish at 100 °C for 24 hours to a constant weight. Per cent wet and dry gluten were calculated.

3. Statistical Analysis

The data was analyzed in Excel sheets and values were expressed as mean, standard deviation. One way analysis of variance (ANOVA) has been used to compare the data obtained for functional properties of finger millet flour, barnyard millet flour, refined wheat flour and their blends.

4. Results & Discussion

Results on functional properties of finger millet, barnyard millet flour and refined wheat flour have been presented in Table 1, while functional properties of finger millet flour

Emulsifying activity (EA) and emulsion stability (ES) were determined by the method of Yasumatsu *et al.* (1972). A 0.7 g flour sample was added to 10 ml of water and dispersed in a blender with a low speed (12000 rpm). Ten ml Peanut oil was added into this suspension and the blending was resumed at high speed (20,000 rpm) for 1 min. The emulsion thus formed was divided equally into two centrifuge tubes and centrifuged at 3200 rpm for 5 min. Emulsifying activity was expressed as the

$$\text{Emulsifying activity (\%)} = \frac{\text{Height of emulsified layer} \times 100}{\text{Height of total contents in the tube}}$$

Emulsion stability was determined with the same method except that emulsion in the centrifuge tube was initially heated in water bath (80°C) for 30 min and subsequently cooled to 24°C before centrifugation. Emulsion stability was measured as the

and barnyard millet flour blends with refined wheat flour have been presented in Table 2.

Water absorption capacity is the amount of water taken up by the flour to achieve the desired consistency or optimal end result. Water absorption gives an indication of the amount of water available for gelatinization. The ability of flour to absorb water depends on the availability of hydrophilic groups which bind water molecules (Kulkarni *et al.*, 2002). Machinability of dough, proofing, loaf volume, the final product attributes and shelf life are essential elements of water absorption (Pylar, 1988). Various factors affect the water absorption capacity of flour like particle size of flour, degree of milling, presence of large proportion of husk in whole flours, percentage of damaged starch in milled flours and protein content of different flours (Singh *et al.*, 2005). The water absorption capacity of finger millet flour, barnyard millet flour and refined wheat flour was found to be 140.77, 158.63 and 131.93 ml, respectively. The high water absorption is the characteristics of fibre supplemented flours as reported by Rasco *et al.* (1991). Therefore, higher water absorption capacity of finger millet and barnyard millet could be attributed to the presence of higher amount of fibre and protein content in these flours. The variation in water absorption in the various millet flours is attributed to differences in particle size of flour, presence of large proportion of husk in whole flours, percentage of damaged starch in milled flours and protein content of different millet flours (Singh *et al.*, 2005). Increased water absorption capacity of finger millet and barnyard millet observed in this study appears to be advantageous in processing, formulation and development of bakery products due to its higher protein content (Akubor and Badifu, 2004; Mepba *et al.*, 2007).

The oil or fat absorption capacity of flour is an important aspect as it improves the mouth feel of the product and retains the flavor (Abulude *et al.*, 2005). The oil absorption capacity of food protein depends upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity. The oil absorption capacity also makes the flour suitable in facilitating

enhancement in flavor and mouth feel when used in food preparation. The ability of the proteins of these flours to bind with oil makes it useful in food system where optimum oil absorption is desired (**Chandra and Samsher, 2013**). The fat absorption of finger millet flour, barnyard millet

flour and refined wheat flour was found to be 141.46, 146.67 and 118.1 ml, respectively. Finger millet flour and barnyard millet flour having higher oil absorption capacity could be therefore being better than the refined wheat flour as flavor retainer.

Table 1: Functional properties of finger millet flour, barnyard millet flour and refined wheat flour

Functional property	Finger millet flour (PRM-15)	Barnyard millet flour (PRJ-1)	Refined wheat flour	S.Em.	CD at 5%
Water absorption(ml)	140.77±0.11 ^a	158.63±0.28 ^b	131.93±0.09 ^c	0.24	0.83
Fat absorption(ml)	141.47±0.27 ^a	146.67±0.52 ^b	118.10±0.15 ^c	0.45	1.55
Sedimentation value (ml)	11.37±0.11 ^a	13.30±0.13 ^b	29.87±0.42 ^c	0.34	1.18
Emulsion activity (%)	18.29±0.06 ^a	25.72±0.01 ^b	42.99±0.34 ^c	0.26	0.88
Emulsion stability (%)	14.23±0.10 ^a	21.17±0.08 ^b	40.70±0.13 ^c	0.13	0.46
Dough raising capacity (%)	19.36±0.03 ^a	27.05±0.11 ^b	92.54±0.17 ^c	0.15	0.52
Wet gluten (%)	1.79±0.06 ^a	2.02±0.05 ^a	26.42±0.37 ^b	0.28	0.96
Dry gluten (%)	0.39±0.01 ^a	0.41±0.02 ^a	9.22±0.12 ^b	0.93	0.32

*All results are mean ± standard error for three replicates

*Different alphabets in superscript in each row show significant difference between values

The sedimentation value is the simple and rapid way to estimate the strength of the flour. The volume of the sediment depends largely on the quantity of gluten in the wheat and the extent to which the gluten is swollen (gluten quality). The test, therefore, is a combined measure of the quantity and quality of gluten (**Zeleny et al., 1960**). Among all three flour sample, refined wheat flour had shown maximum sedimentation value of 29.87 ml, while finger millet flour had minimum sedimentation value of 11.37 ml. Barnyard millet flour showed sedimentation value of 13.30 ml. The lower sedimentation value of finger millet flour and barnyard millet flour showed the lower gluten quality of both the millet flour as compared to refined wheat flour.

Emulsion activity is a major determinant of dough strength. A protein-protein interaction due to hydrophobic interaction on the surface of the protein would form a strong oil-water interface resulting in a stable emulsion (**Mao and Hua, 2012**). Emulsion activity and emulsion stability of finger millet flour were found to be lowest (18.29 and 14.23 per cent, respectively), while refined wheat flour had maximum emulsion activity and emulsion stability (42.99 and 40.70 per cent, respectively). Barnyard millet flour showed emulsion activity and stability of 25.72 and 21.17 per cent, respectively. The dough raising capacity of finger millet flour, barnyard millet flour and refined wheat flour was found to be 19.36, 27.05 and 92.54 per cent, respectively. Water absorption capacity contribute to dough formation and stability, while fat absorption and emulsion capacities are important factors in baking that contribute to texture of bread (**Olapade and Oluwole, 2013**). Soluble proteins are surface active and promote formation and stabilization of oil-in-water emulsion (**Onimawo and Akubor, 2012**). It is likely that the high insoluble components; including proteins and fibres in finger millet and barnyard millet flour may have discouraged formation of emulsion (**Badifu et al., 2000**). However, these properties of both millet flours could be improved by blending it with wheat flour. The dough raising capacity of the refined wheat flour was significantly higher (92.54 per cent) as compared to barnyard millet flour (27.05 per cent) and finger millet flour (19.36 per cent).

Gluten formation is critical to the volume, texture and appearance of a product. When the proteins in the flour

are hydrated and the dough/batter is mixed, gluten bonds form providing structure and elasticity and form elastic dough. Sufficient gluten production gives rise to a light product with good volume (**www.jessicagavin.com, 2017**). Gluten is a complex group of seed storage proteins of cereals, which account for a high percentage of the cereal protein content. In general, gluten contains two main protein fractions, gliadin which contribute essentially to the viscosity and extensibility of the dough system and glutenins which are responsible for dough strength and elasticity (**Xu et al., 2007**). The combination of these two fractions results in the gluten complex; which becomes apparent when flour is hydrated, leading to an extensive dough, with good gas holding properties and good crumb structure in baked bread. Gluten, therefore, exhibits cohesive, elastic and viscous properties that combine the extremes of the two components. Gluten is often termed as the 'structural' protein for breadmaking. The finger millet flour had wet and dry gluten content of 1.79 and 0.39 per cent, respectively. While barnyard millet flour had wet gluten content of 2.02 percent and dry gluten content of 0.41 per cent. The wet and dry gluten content of refined wheat flour was found to be highest (26.42 per cent and 9.22 per cent, respectively). All three flour samples were significantly different from each other in all functional properties except gluten content. Gluten content of both millet flours was non significantly different from each other. The lower gluten content of finger millet and barnyard millet flour indicates their poor bread making quality, which can be improved by blending these flours with wheat flour.

Flour from the finger millet and barnyard millet were mixed separately with refined wheat flour in the ratio of 30:70, 40:60, 50:50 and 60:40 (millet flour: refined wheat flour) and evaluated for functional properties.

The water absorption capacity of finger millet flour blends (viz: 30:70, 40:60, 50:50 and 60:40) increased from 133.13 ml/g (blend with 30 per cent finger millet flour incorporation) to 137.63 ml/g (blend with 60 per cent finger millet flour incorporation) with increase in finger millet incorporation. **Choudhary and Jood (2013)** reported the increasing trend in water absorption capacity in finger millet flour blends (5 %, 10 %, 15 % and 20 % finger millet

incorporation) with maximum water absorption capacity in 20 per cent finger millet flour blend.

Barnyard millet flour blends (viz: 30:70, 40:60, 50:50 and 60:40) also showed gradual increase in water absorption capacity from 134.50ml/g (blend with 30 per cent barnyard millet flour incorporation) to 141.90 ml/g (blend with 60 per cent barnyard millet flour incorporation) with increase in barnyard millet flour incorporation. All the millet flour blends were significantly different from each other as well

as from refined wheat flour in context of water absorption capacity. Fibre is characterized by high water holding capacity as reported by **Holloway et al. (1984)**. Therefore, increased fibre content in finger millet flour and barnyard millet flour blends could be one possible reason of increased water absorption capacity. Water absorption capacity is important in bulking and consistency of products as well as in baking applications.

Table 2: Functional properties of blends of finger millet flour and refined wheat flour, and barnyard millet flour and refined wheat flour

Blends RWF:FMF	100:0	70:30	60:40	50:50	40:60	S.Em.	CD at 5%
Water absorption(ml)	131.93±0.21 ^a	133.13±0.31 ^b	134.5±0.26 ^c	136.27±0.29 ^d	137.63±0.31 ^e	0.19	0.59
Fat absorption(ml)	118.10±0.15 ^a	123.20±0.12 ^b	126.43±0.07 ^c	129.00±0.12 ^d	131.43±0.13 ^e	0.16	0.49
Sedimentation value (ml)	29.87±0.42 ^a	23.13±0.11 ^b	20.47±0.14 ^c	16.97±0.09 ^d	14.70±0.08 ^e	0.27	0.86
Emulsion activity (%)	42.99±0.34 ^a	33.97±0.38 ^b	29.80±0.38 ^c	25.72±0.47 ^d	23.14±0.33 ^e	0.49	1.56
Emulsion stability (%)	40.70±0.13 ^a	32.47±0.17 ^b	28.02±0.22 ^c	24.27±0.19 ^d	21.33±0.22 ^e	0.25	0.77
Dough raising capacity (%)	92.54±0.17 ^a	60.27±0.37 ^b	48.15±0.20 ^c	35.01±0.24 ^d	27.33±0.21 ^e	0.32	1.00
Wet gluten (%)	26.42±0.37 ^a	17.07±0.12 ^b	14.32±0.20 ^c	9.14±0.04 ^d	5.00±0.06 ^e	0.25	0.79
Dry gluten (%)	9.22±0.12 ^a	5.87±0.15 ^b	4.37±0.14 ^c	2.84±0.09 ^d	0.84±0.02 ^e	0.15	0.47

Blends RWF:BMF	100:0	70:30	60:40	50:50	40:60	S.Em.	CD at 5%
Water absorption(ml)	131.93±0.09 ^a	134.50±0.16 ^b	136.23±0.16 ^c	137.13±0.10 ^d	141.90±0.09 ^e	0.16	0.51
Fat absorption(ml)	118.10±0.15 ^a	124.37±0.13 ^b	127.77±0.05 ^c	131.33±0.09 ^d	134.53±0.10 ^e	0.15	0.47
Sedimentation value (ml)	29.87±0.42 ^a	24.77±0.07 ^b	22.83±0.05 ^c	19.43±0.10 ^d	17.63±0.14 ^e	0.27	0.84
Emulsion activity (%)	42.99±0.34 ^a	36.74±0.30 ^b	34.72±0.09 ^c	30.44±0.39 ^d	27.33±0.22 ^e	0.37	1.17
Emulsion stability (%)	40.70±0.13 ^a	35.27±0.14 ^b	33.12±0.30 ^c	28.75±0.31 ^d	24.27±0.19 ^e	0.29	0.92
Dough raising capacity (%)	92.54±0.17 ^a	66.90±0.18 ^b	54.44±0.17 ^c	42.58±0.14 ^d	32.86±0.22 ^e	0.23	0.73
Wet gluten (%)	26.42±0.37 ^a	21.20±0.31 ^b	16.99±0.05 ^c	12.86±0.05 ^d	7.15±0.09 ^e	0.29	0.90
Dry gluten (%)	9.22±0.12 ^a	7.22±0.15 ^b	5.39±0.08 ^c	3.54±0.02 ^d	1.33±0.02 ^e	0.12	0.39

*All results are mean ± standard error for three replicates

*Different alphabets in superscript in each row show significant difference between values

The blends of both finger millet flour and barnyard millet flour showed increasing trend in fat absorption capacity with increase in proportion of millet flour. In case of blends of finger millet flour and refined wheat flour, fat absorption capacity increased from 123.20 ml/g (blend with 30 per cent finger millet flour incorporation) to 131.43 ml/g (blend with 60 per cent barnyard millet flour incorporation), while in case of barnyard millet flour blends it was found to be increased from 124.37 ml/g (blend with 30 per cent barnyard millet flour incorporation) to 134.53 ml/g (blend with 60 per cent barnyard millet flour incorporation). All the blends differed significantly from each other and refined wheat flour. **Singh et al. (2005)** also observed the similar increasing trend in fat absorption capacity of millet flour blends after increased incorporation of millet flour. Due to high fat absorption capacity of finger millet flour and barnyard millet flour, these have tendency to increase the mouth feel and retention of flavour of the food products in which they are incorporated. High oil absorption capacity means that various kinds of lipophilic components can be adsorbed effectively by finger millet and barnyard millet (**Akubor and Badifu, 2004**).

The finger millet flour blend having 30% finger millet flour incorporation had sedimentation value of 23.13 ml, which decreased gradually with increase in finger millet flour. The sedimentation value of 60% finger millet flour incorporated flour blend was found to be 14.70 ml. Similar decreasing trend in sedimentation value after finger millet flour

incorporation was observed by **Choudhary and Jood (2013)**. The barnyard millet flour blends also showed decreasing trend in sedimentation value with increased incorporation of barnyard millet flour. It decreased from 24.77 ml (blend with 30 per cent barnyard millet flour incorporation) to 17.63 ml (blend with 60 per cent barnyard millet flour incorporation) and differed significantly from each other and refined wheat flour. The poor sedimentation value of finger millet and barnyard millet flour blends indicate the poor gluten quality of the both millet flours which directly affect the baking quality.

The finger millet flour blends showed decreasing pattern from 33.97 per cent (blend with 30 per cent finger millet flour incorporation) to 23.14 per cent (blend with 60 per cent finger millet flour incorporation) in emulsion activity, while emulsion stability of above blends found to be decreased from 32.47 to 21.33 per cent, respectively. Each proportion differed significantly from each other and refined wheat flour in both properties. The emulsion activity of barnyard millet flour blends showed a decreasing trend on increasing millet flour incorporation. It decreased from 36.74 per cent (blend with 30 per cent barnyard millet flour incorporation) to 27.33 per cent (blend with 60 per cent barnyard millet flour incorporation). Emulsion stability also showed similar trend and decreased from 35.27 per cent (blend with 30 per cent barnyard millet flour incorporation) to 24.27 per cent (blend with 30 per cent barnyard millet flour incorporation)

on millet flour incorporation. Each blend showed significant difference from each other.

A decreasing pattern was seen in the dough raising capacity with increased millet flour incorporation. In finger millet flour blends, it decreased from 60.27 per cent (blend with 30 per cent finger millet flour incorporation) to 27.33 per cent (blend with 60 per cent finger millet flour incorporation), while in barnyard millet blends, the dough raising capacity decreased from 66.90 per cent (blend with 30 per cent barnyard millet flour incorporation) to 32.86 per cent (blend with 60 per cent barnyard millet flour incorporation). All the millet flour blends differ significantly from each other, as well as from refined wheat flour.

With increased incorporation of finger millet and barnyard millet flour, the gluten content was found to be decreased. The wet and dry gluten content of finger millet flour blends decreased from 17.07 per cent (blend with 30 per cent finger millet flour incorporation) to 5.00 per cent (blend with 60 per cent finger millet flour incorporation) and 5.87 per cent (blend with 30 per cent finger millet flour incorporation) to 0.84 per cent (blend with 60 per cent finger millet flour incorporation), respectively. **Choudhary and Jood (2013)**, also reported the similar decreasing trend in gluten content with increased finger millet flour incorporations in finger millet and refined wheat flour blends. As per their study, the wet and dry gluten content of wheat flour was 29.51 and 9.93 per cent, respectively, which was decreased to 28.82 and 9.49 per cent, respectively after incorporation of 5 per cent finger millet flour. Barnyard millet flour blends showed decrease in wet and dry gluten content from 21.20 per cent (blend with 30 per cent barnyard millet flour incorporation) to 7.15 per cent (blend with 30 per cent barnyard millet flour incorporation) and 7.22 per cent (blend with 30 per cent barnyard millet flour incorporation) to 1.33 per cent (blend with 30 per cent barnyard millet flour incorporation), respectively. Significant difference was found between millet flour blends and refined wheat flour.

5. Conclusion

Functional properties viz. water absorption capacity, fat absorption capacity, sedimentation value, emulsion activity and emulsion stability, dough raising capacity and gluten content are the essential determinants of the baking properties of flour. Incorporation of different millet flours in conventionally used refined wheat flour can alter the functional properties of the flour and consequently the physical, textural and sensory characteristics of the baked products. The water absorption and fat absorption of the finger millet as well as barnyard millet flour was higher due to more fibre and protein content, than the refined wheat flour, therefore the blends with different proportions of finger millet flour and barnyard millet flour showed gradual increase with millet flour incorporation. Though other functional properties of finger millet flour and barnyard millet flour were lower than the refined wheat flour, due to which blends of finger millet flour and barnyard millet flour also showed gradual decrease with increased millet flour incorporation.

6. Acknowledgement

The authors acknowledge Department of Foods and Nutrition, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand for providing all the facilities and guidance during the course of research work and University Grants Commission (New Delhi) for providing financial assistance through Junior Research Fellowship (JRF) programme.

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