International Journal of Food Science and Nutrition
ISSN: 2455-4898; Impact Factor: RJIF 5.14
Received: 01-10-2020; Accepted: 15-10-2020; Published: 04-11-2020
www.foodsciencejournal.com
Volume 5; Issue 6; 2020; Page No. 38-42

Development of low-cost high nutrients density weaning foods based on biofortified pearl millet

Mwanamvua Zuberi[1*], Veenu Sangwan[2]
[1] Nutritionist, Health Department, Regional Administrative Secretary, Tanga, Tanga, Tanzania
[2] Department of Foods & Nutrition, CCS Haryana Agricultural University, Hisar, Haryana, India

Abstract
The study aimed to develop low cost, high nutrient and easily digestible weaning foods based on domestically processed bio fortified pearl millet in combination with chickpea and skimmed milk powder. Household processing techniques i.e. malting (germination at 30^0 for 48hr) and roasting at 200^0C for 15 minutes were employed to improve the nutrient availability and shelf life of pearl millet. Moisture, protein, fat, ash, crude fibre and carbohydrate content in weaning foods ranged from 1.17-2.43, 15.46-18.99, 4.43-6.7, 2.77-3.30, 1.52-2.4 and 68.51-71.98 %, respectively. Malting significantly ($P<0.05$) increased protein digestibility up to 75.59 % and starch digestibility up to 84.4% while roasting also significantly ($P<0.05$) increased protein digestibility up to 72.93% and starch digestibility up to 60.2%. Energy contents ranged from 389.63 to 414.02 kcal/100g of meal. The products could cost Rs. 10-12/100g. The pearl millet and legume based weaning mix has colossal potential for augmenting child nutrition status in low income families.

Keywords: bio fortified, pearl millet, malting, roasting, weaning, digestibility

1. Introduction

1.1 Background of the study

In developing countries like Tanzania malnutrition in all its forms (undernutrition dominant) is endemic, especially to children under the age of five years. This can be due to abrupt weaning of child to semisolid traditional starchy foods, which are characterised with high bulk and low nutrients density; and sometimes tough to be assimilated.
Breast milk is the best for infants up to six months of age, after that it is not enough to fulfil physiological requirements and optimum growth [1]. Therefore, after six months of age, with continual breast feeding, infant has to be supplemented with high nutrient-dense weaning foods to circumvent and overcome malnutrition. The protein of high biological value is the most dietary deficit in the community especially those of low socio economic status. Proteins of animal products are of high biological values. However, we cannot overcome protein deficiency by using animal products because they are not easily affordable [2]. Combination of cereals and legumes will complement each other to form foods with nutritional value as good as animal protein. Most of commercially available weaning foods, having various modifications and supplementation of nutrients to meet nutritional requirements of infants are costly and therefore not affordable to low income families. The use of locally available and domestically processed staples (especially cereals and legumes) to formulate low cost high nutrients density weaning foods have gained importance in many researches.

1.2 Problem statement

Commercial weaning foods are expensive and therefore out of reach of low-income families which are majority in the developing countries. Commonly used weaning foods are of low nutrients density, and therefore the major cause of malnutrition and poor health status especially to children under the age of five years.

1.3 Justification

The results from this study will enlighten the community on the use of simple domestic techniques (malting and roasting) to produce low cost nutrients dense weaning foods from biofortified pearl millet and chickpea, however knowledge can be applied to other locally available staples. Also this will help researchers, breeders and policy makers (government) to put more emphasis on biofortification (iron and zinc rich) of local staples.

1.4 Aim and objectives

The aim and broad objective of this study was to develop low cost nutrients dense weaning foods from biofortified pearl millet and chickpea, to access nutritional composition, energy content and cost analysis.

2. Materials and methods

2.1 Selection of raw materials

The selection of materials was based on their superiority in macro and micro nutrients. Materials used in this study included biofortified pearl millet (HHB 299), chickpea (HC 5) and skimmed milk powder. Pearl millet grains were selected as they have been reported to be nutritionally superior to major cereals with respects to protein, energy, vitamins and minerals [3, 4]. Using millet in weaning food not only will provide macronutrients like protein and energy for the growth and development, but also the plenty of vitamins and minerals present together with nutraceuticals will endow protective role to prevent infections which are more common to infants and young children. Chickpea is rich source of protein, carbohydrates, trace minerals and folate [5]. Skimmed milk powder is stable during storage due to low fat content, and it is rich in protein with balanced essential amino acids and high digestibility [6]. Combination of pearl millet, chickpea and skimmed milk powder will complement each other, there by resulting in availability of particular nutrients that were deficient or absent in individual group, hence, making accessible weaning food that meets nutritional requirements of infant.

2.2 Procurement of materials
Pearl millet (HHB 299) and chickpea (HC 5) were procured from the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, India. Skimmed milk powder, vegetable oil and sugar were purchased in a single lot from local market of Hisar, India.

2.3. Processing of pearl millet
Pearl millet grains were divided into two portions, one portion was roasted and the other portion was malted.

2.3.1 Malting
Pearl millet malt was prepared by germinating grains at 30^o C for 48 hours [7]. The grains were soaked in a germinating dish using double the amount of 0.1 per cent formaldehyde solution. The mouth of the dish was covered with a muslin cloth using rubber band and the grains were allowed to soak for 6 hours at 25^{0}C – 30^{0}C in an incubator. The water (unimbibed) was drained off in presence of covered muslin cloth. Aeration was done by removing cloth for a period of 3 hours, in a well-ventilated room so as to enhance enzyme activity. Grains were rotated occasionally by glass rod and re-steeped with fresh formaldehyde solution for a period of 16 hrs and the mouth of the dish was again covered. The soaked seeds were sprayed with 25 ml of 0.1 per cent formaldehyde solution to prevent the mould growth and allowed to germinate in an incubator at 30^0 C for 48 hrs. The germinated grains were dried in hot air oven at 50^{0}C for 24 hours. The kilning seeds were rubbed in hands and sieved to remove thin pieces of sprout. Finally cleaned malted seeds were grounded in an electric grinder (Cyclotec, M/s Tecator, Hoganas, Sweden), the flour obtained was sieved through a 60 mesh sieve and packed in an air tight laminated pouch for further use.

2.3.2 Roasting
The pearl millet seeds were roasted in a pan over stove at 200^{0}C for 15 minutes. While roasting, the seeds were rotated thoroughly to avoid burning. The seeds were grounded in an electric grinder (Cyclotec, M/s Tecator, Hoganas, Sweden), the flour obtained was sieved through a 60 mesh sieve and packed in an air tight laminated pouch for further use.

2.3.3 Processing of chickpea
Chickpea was first cleaned to remove dust, extraneous material and damaged seeds. The cleaned chickpea seeds were roasted in a pan over stove at 200^{0}C for 20 minutes. While roasting, the seeds were rotated thoroughly to avoid burning. The seeds were grounded in an electric grinder (Cyclotec, M/s Tecator, Hoganas, Sweden), the flour obtained was sieved through a 60-mesh sieve and packed in an air tight laminated pouch for further use.

2.4 Formulation of weaning flour mix
Guidelines on how to develop recipes for weaning foods [8, 9], was used to estimate optimum amount of chickpea and skimmed milk powder to be added in pearl millet flour in order to meet the energy and protein requirement of infants And young children. Details of various combination of pearl millet flour, chickpea flour and skimmed milk powder used in formulation of weaning flour mix are indicated in Table 1.

2.5 Nutrients composition of weaning flour mix
2.5.1 Proximate composition
Pearl millet based weaning flour mix were analysed for moisture, crude fat, crude protein, ash and crude fibre content [10]. Total carbohydrate was determined by "difference method". The sum values (per 100 g) of moisture, protein, fat, ash and crude fibre was subtracted from 100 to get carbohydrate content.

2.5.2 *In-vitro* studies
2.5.2.1 *In vitro* protein digestibility
Determniation of *in vitro* protein digestibility was done [11]. The protein digestibility was expressed as percentage (%).

$$\text{Protein digestibility (\%)} = \frac{\text{Digested protein}}{\text{Total protein}} \times 100$$

2.5.2.2 *In vitro* starch digestibility
In vitro starch digestibility was assessed [12]. *In vitro* starch digestibility was expressed as mg maltose released/g meal.

$$\textit{In vitro}\text{ starch digestibility} = \frac{\text{Concentration from the graph (mg)}}{\text{Weight of sample (g)}} \times 100$$

2.6. Energy estimation and cost analysis
2.6.1 Energy content
The energy value of weaning flour mix was calculated by multiplying the protein and carbohydrate content of the weaning flour mix by 4.0 and multiplying the fat content of the weaning flour mix by 9 for getting energy supplied by each protein, fat and carbohydrate content of weaning flour mix. The energy thus calculated from protein, fat and carbohydrate were the added to get total energy supplied by the weaning flour mix.

2.6.2 Cost of weaning flour mix
Market price of ingredients were used for price calculations of the formulated weaning flour mixes. Details of the cost estimates are provided in Table 2.

2.7. Contribution of formulated weaning flour mix to RDA
The contribution of formulated weaning flour mix to recommended dietary allowance was expressed as % of RDA

% RDA=X/Y multiply by 100

Where X is the amount of analyzed nutrient and Y is the RDA for a given nutrient

2.8. Statistical analysis
All the determinants were performed in triplicates and analyzed statistically using standard methods of analysis [13]. Significance of variation was accepted at $p<0.05$.

3. Results and Discussion

Table 1: Formulation of weaning flour mix based on processed pearl millet, processed chickpea and skimmed milk powder

	Proportion			
Ingredients	**T1**	**T2**	**T3**	**T4**
RPMF (%)	0	0	50	60
MPMF (%)	50	60	0	0
RCF (%)	30	20	30	20
SMP (%)	15	15	15	15
Sugar + Vegetable oil* (%)	5	5	5	5

RPMF- Roasted Pearl Millet Flour RCF- Roasted Chickpea Flour SMP- Skimmed Milk Powder MPMF- Malted Pearl Millet Flour *were added at the time of serving of weaning food for organoleptic evaluation.

Table 2: Market price of the ingredients used in formulating weaning flour mix

Ingredients	Cost (Rs/Kg)
Pear millet	50
Chickpea	70
Skimmed milk powder	375

3.1. Proximate composition

Table 3 shows proximate composition of processed pearl millet and chickpea based weaning flour mixes. The results indicated that moisture content was significantly (P≤0.05) higher in weaning flour mix containing 60% malted pearl millet flour. Moisture content of weaning flour mix was within the acceptable limit recommended for cereals based weaning foods [14]. The results further indicated that, increased amount of chickpea flour significantly (P≤0.05) increased protein and fat content of weaning flour mixes. Increase in fat content of weaning foods with increase in legume fraction had also been reported earlier [15, 16].

Table 3: Proximate composition of processed pearl millet and chickpea based weaning flour mixes (g/100g, on dry matter basis)

Weaning flour mix	Moisture*	Crude Protein	Fat	Ash	Crude Fibre	Carbohydrate
T1: 50% MPMF + 30% RCPF	1.73±0.03	17.48±0.06	5.65±0.01	2.99±0.09	1.73 ±0.06	70.42±0.01
T2: 60% MPMF + 20% RCPF	2.43±0.09	15.46±0.03	4.43±0.01	3.30±0.07	2.4±0.06	71.98±0.00
T3: 50% RPMF + 30% RCPF	1.48±0.06	18.99±0.06	6.73±0.003	2.77±0.07	1.52±0.05	68.51±0.00
T4: 60% RPMF + 20% RCPF	1.17±0.09	17.91±0.09	6.03±0.01	2.87±0.01	1.97±0.05	70.05±0.02
C.D. (P≤0.05)	0.4	0.25	0.29	0.3	0.26	0.6

Values are mean ± SE of three independent determinations MPMF- Malted Pearl Millet Flour RPMF- Roasted Pearl Millet Flour RCPF- Roasted Chickpeas Flour SMP- Skimmed Milk Powder ***** Fresh weight basis

The crude protein content ranged from 15.46 to18.99 per cent. It is recommended that protein content of cereal based weaning foods should not be less than 15 percent[14]. Reported high protein content in formulated weaning flour mixes is attributed to supplementation of chickpea flour and skimmed milk powder in the formulations. There was slight increase in ash content due to increase in amount of malted pearl millet flour. The results obtained from this study collaborated with those reported earlier [17], who found ash content of pearl millet based composite flour ranged from 2.15 to 2.64 per cent. Formulations containing 60 per cent pearl millet flour observed to have high crude fibre content compared to formulations containing 50 per cent pearl millet flour. Incorporation of 60 per cent pearl millet malt in weaning food mixes resulted to an increase in fibre content from 1.57 to 1.86 per cent, the increase in fibre content can be due to synthesis of cellulose and hemicellulose during malting which act as structural carbohydrates [18]. Carbohydrate content ranges from 68.51 to 71.98 per cent. High carbohydrate in weaning mixes is very crucial to meet energy requirement, it is recommended that carbohydrate should contribute 45-65 per cent of total daily energy intake[1]. Results obtained from this study are in agreement with the one which reported carbohydrate content ranged from 72.69 to 73.72g/100g in weaning mixes formulated with cereals, pulses and skimmed milk powder [19].

3.2. In vitro digestibility

Starch digestibility of malted weaning foods (T1 & T2) ranged 80.12 to 84.4 mg maltose released/g of meal whereas that of roasted weaning foods (T3 & T4) ranged from 58.93 to 60.2 mg maltose released/g of meal. Protein digestibility of malted weaning foods (T1 & T2) ranged from 73.83 to 75.59 while protein digestibility of roasted weaning mix ranged from 70.65 to 72.93. Malting and roasting significantly ($p < 0.05$) improved digestibility of cereals and legumes weaning foods with higher effect being in malted weaning mixes [20, 21, 22].

Table 4: *In-vitro* digestibility of processed pearl millet based weaning flour mix (on dry matter basis)

Weaning flour mix	Protein Digestibility (%)	Starch Digestibility (mg maltose released/g of meal)
T1: 50% MPMF + 30% RCPF	73.83±0.08	80.12±0.16
T2: 60% MPMF + 20% RCPF	75.59±0.02	84.4±0.12
T3: 50% RPMF + 30% RCPF	70.65±0.1	60.2±0.36
T4: 60% RPMF + 20% RCPF	72.93±0.02	58.93±0.36
C.D. (P≤0.05)	0.963	1.04

Increment in the protein and starch digestibility of developed weaning mix might be due to increase in activities of enzymes such as amylases and proteases, as a result of malting and roasting, which rupture complex carbohydrates and proteins in grains and render them to become more digestible. Malting and roasting decreased antinutritional factors such as phytates, tannins and amylase inhibitors, as well as resulted in activation of enzymes, which to some extent were responsible for the improved digestibilities.

3.3 Energy estimation and cost analysis

The energy value of the composite flour mix ranged from 389.63 to 406.11 Kcal/100g (Table.5). Significant (P≤0.05) increase in energy content was recorded in processed weaning mixes, as it was expected, was due to increased fat content. The cost of the formulated weaning flour mix ranged from 10 to 12 Rs /100g. The cost of the formulated weaning flour mix was compared with the cost of cereals based commercial products (190 Rs /100g) and observed that, the cost of cereals based commercial was more than thirteen times higher than that of formulated products.

Table 5: Energy value and cost of weaning flour mix

Weaning composite flour mix	Energy* (Kcal/100g)	Cost (Rs /100g)
T1: 50% MPMF + 30% RCPF + 15% SMP	402.45	12
T2: 60% MPMF + 20% RCPF + 15% SMP	389.63	10
T3: 50% RPMF + 30% RCPF + 15% SMP	410.57	12
T4: 60% RPMF + 20% RCPF + 15% SMP	406.11	10
C.D. (P≤0.05)	1.442	

*Values are mean ± SE of three independent determination

3.4. Contribution (%) of fat, protein and energy content of weaning flour mix to the daily recommended allowance of children aged 6-59 months.

The findings (Table 6) revealed that contribution (%) of fat, protein and energy content of weaning flour mix to the daily recommended allowance decreased with increasing age of child. Fat content of T1 weaning mix contributed 33.83 percent to RDA of 1-3 years age group of children and 24.25 percent to 4-6 age group. The same trend was observed in T2, T3 and T4 weaning mixes. For the children 0.5 – 3 years, contribution of protein content of weaning flour mixes to RDA ranged from 96.63 to 135.64 per cent, but it ranged 64.42 to 79.13 per cent for the children 4 –6 years.

Table 6: Contribution (%) of fat, protein and energy content weaning flour mix to their daily recommended allowance of children aged 6-59 months.

			Contribution (%) of weaning flour mix to RDA			
Variable	Age group (years)	RDA	T1	T2	T3	T4
Fat(g/day)	0.5-1					
	1-3	16.7**	33.83	26.53	40.30	36.11
	4-6	23.3**	24.25	19.01	28.88	25.88
Protein (g/day)	0.5-1	14*	124.86	110.43	135.64	127.93
	1-3	16*	109.25	96.63	118.69	111.94
	4-6	24*	72.83	64.42	79.13	74.63
Energy	0.5-1	850*	47.35	45.84	48.30	47.78
	1-3	1300*	30.96	29.97	31.58	31.24
	4-6	1800*	22.36	21.65	22.81	22.56

*23 **24

The high contribution of the formulated weaning foods to RDA of protein is due to high concentration of this nutrient in the formulations (Table.3). The contribution of formulation to protein was slightly above RDA, however it Fells within the acceptable limit [23] (not more than twice the RDA). The formulations contributed nearly 50 % to RDA of energy for 0.5 – 1 year age group and the contribution observed to decrease with increasing age. Addition of sugar and oil during cooking will improve palatability and add energy value to the weaning foods. Reduction in the RDA contribution of both fat, protein and energy with increasing age is due to the increased need of the nutrients for the growing children. As the child grow metabolic need increases. Fat are essential for brain development, transportation of fat soluble vitamins as well as supply of calories. Protein is necessary for development and growth of children while energy is required for body maintenance and other metabolic needs.

4. Conclusion

The use of malted and roasted pearl millet, incorporating chickpea and skimmed milk powder resulted in development of low cost nutrients dense weaning flour mix. Production and use of these pearl millet based weaning flour mix can contribute to meet nutritional requirements, and therefore improving nutritional status of children especially in developing countries where low socio income families cannot afford expensive market weaning products. Moreover, utilization of pearl millet will help to achieve food and nutrition security especially in Asian and African countries; and help pearl millet find appropriate place in emerging nutrition markets.

5. References

1. PAHO/WHO. “Guiding Principles for Complementary Feeding of the Breastfed Child”, Division of Health Promotion and Protection, Food and Nutrition Program,

Pan American Health Organization/ World Health Organization, Washington/Geneva, 2003.
2. Okorie SU, Ekwe CC. The comparative analysis of sprouted legume and cereal based composite diet. Applied Biotechnology & Bioengineering. 2017; 4(2):554-561. DOI: 10.15406/jabb.2017.04.00099
3. Sehgal, Kawatra. Alternative Uses of Sorghum and Pearl Millet in Asia. CFC and ICRISAT (2003). In Proceedings of a Consultants Meeting, 2004.
4. Ragaee S, Abdel-Aal ESM, Noaman M. Antioxidant activity and nutrient composition of selected cereals for food use. Food Chemistry. 2006; 98:32-38.
5. Threinen D, Hansen, Mand Driedger D. Effects of extrusion condition on system parameters and physical properties of chickpeas flour based snacks. Food and Research International. 2010; 43(2):650-658
6. Hoffman JR, Falvo MJ. Protein - Which is best? Sports Science and Medicine. 2004; 3:118-130.
7. Chaturvedi A, Sarojini G. Malting of pearl millet (*Pennisetum typhoideum*): its effect on starch and protein digestibilities. Food Sci Technology. 1996; 33:342-344.
8. Bolina P. Nutritious recipes for complementary feeding of infants and young children. Food and Nutrition Board Ministry of Women and Child Development, Government of India, 2008.
9. Cameron M, Hofvander Y. How to develop recipes for weaning foods? Oxford University Press, Delhi, India, 1983, 117-31
10. AOAC. Official Methods of Analysis. Association of Official Analytical Chemist. Washington, D.C, 2010.
11. Mertz ET, Kiresis AW, Sxtell JD. *In-vitro* digestibility of protein in major food cereals. Federation Proceedings. 1983; 32(5):6029-6031
12. Singh U, Kherdeker MS, Jambunathan R. Studies on desi and kabuli chickpea (*Cicer arietinum L.*) cultivars, the levels of amylase inhibitors, levels of oligosaccharides and *in vitro* starch digestibility. Journal ofFood Science. 1982; 47(2):412-510.
13. Sheoran OP, Pannu RS. Statistical Package for agricultural workers. "O.P. Stat" College of Agriculture, Kaul, CCS Haryana Agricultural University, Hisar. India, 1999.
14. Food Safety and Standards (Foods for Infant Nutrition) Regulations (FSSR), 2017.
15. Bazaz R, Waqas NB, Farooq A. Development and quality evaluation of hypoallergic complementary foods from rice incorporated with sprouted green gram flour. Cogent Food & Agriculture. 2016; 2:1. Available at https://doi.org/10.1080/23311932.2016.1154714
16. Hussain I, Uddin MB. Study of microbial flora on germinated wheat and mungbean seeds flour. International Journal of Food Safet. 2011; 13:38-40.
17. Maryann MK, Arnold O, Florence K. Effects of Processing on Nutritional and Sensory Quality of Pearl Millet Flour. Food Science and Quality Management. 2015; 42: 13-19.
18. Talib MI, Akshay TB, Vishal RP. Development of Weaning Food from Pearl Millet Malt. International Conference Proceeding ICGTETM, 2017. ISSN: 2320-2882.
19. Vasantha PK, Narayanasamy S. Nutritional significance of cereals and legumes based food mix. International Journal of Agricultural and Life Sciences. 2017; 3(1):115-122.
20. Tumwine G, Abel A, Gaston A, Fransis T, Anita L. Production of nutrient-enhanced millet-based composite flour using skimmed milk powder and vegetables. Food Sci Nutr. 2018; 7:22-34.
21. Suma PF, Urooj A. Influence of processing on dietary fiber, tannin and *in vitro* protein digestibility of pearl millet. Food and Nutr Sci. 2017; 2:859-900.
22. Gahlawat P, Sehgal S. Protein and starch digestibility and iron availability in developed weaning foods as affected by roasting. Human Nutrition and Dietetics. 2008; 7:121-126. Doi. 10.1111/j.1365-277X. 1994. tb00419.x.
23. National Research Council. Recommended Dietary Allowance. The National Academy Press, Washington DC, 1989.
24. Alasfoor D, Rajab, Al-Rassasi B. Food based dietary guidelines. Ministry of Health, Sultanate of Oman, 2009.