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Evaluation of the Protein Quality of Health Mix Produced from Selected Millets and Pulse for Young Children

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Abstract

The purpose of this study was to formulate a nutrition supplementary mix for young children (1-3 years) from locally available millets and pulse with addition of 20 per cent milk powder that would promote growth and prevent malnutrition. Totally six formulations were standardized using three drying methods namely cabinet, drum and spray drying techniques from germinated finger millet and little millet and analysed for nutritional and protein quality. Highest amount of protein, calcium, magnesium, potassium and iron content (26.04 g, 1272.13 mg, 74.26 mg, 28.3 mg and 5.61 mg/100g respectively was found in T_{1C} formulation prepared using millet dried on cabinet drier methods. Maximum value for PER, TPD, BV, NPU were recorded as 1.73, 90.16, 81.52, 73.49 in T_{1S} formulation prepared using spray drying technique method. Based on the results, the formulated supplementary foods have good protein quality and can be promoted for improving the health and nutritional status of young children and meeting nutritional requirements.

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Keywords

Food formulation, Nutrient composition, protein quality and Target groups.

Introduction

The critical period where children develop malnutrition coincides with the introduction of supplementary foods, which are nutritionally inadequate in many developing countries (Khanam *et al.,* 2011). During this period, children are generally given foods made of cereals or tubers. However, these foods are bulky, low in energy and do not provide important micronutrients such as vitamin A, iron and zinc. Further, feeding such foods under poor hygienic condition increases the risk of gastrointestinal infections and growth faltering in young children (Sharma, 2013). If such foods with low nutrient density are used as staples, children need to be fed large amounts of these foods at each feed in order to fulfill the nutrient requirements. This is generally not practicable given the small stomach capacity of children (Maleta *et al.,* 2004). Besides feeding such bulky cereal-based foods, many mothers feed commercial weaning foods but often dilute these because of their high cost resulting in inadequate nutrient intakes (Nazni *et al.,* 2009).

These limitations can be overcome by making available affordable, ready-to-use supplementary foods that are energy-dense and do not require further processing before consumption. Household processing techniques such as roasting, germination and fermentation could be adopted for improving the nutrient content of supplementary foods. Germination and processing can be used to increase the energy content and nutrient density of supplementary foods and also to assure product safety.

Finger millet is indigenous minor millet used in the preparation of geriatric, infant food and health foods both in natural and malted forms. It is usually used for preparation of flour, pudding, porridge and roti (Chaturvedi and Srivastava, 2008). Similarly little millet is nutritionally superior to rice and wheat and provide cheap protein, minerals, vitamins and fibre and are rightly designated as nutritious cereals (Seetharama and Rao, 2004).

There is a need for nutritionally balanced, energy-dense, easily digestible foods with functional benefits to be formulated. A cost-effective nutritious and functional multi-nutrient food mix prepared using locally available raw materials, which is easily assimilated by the body and promotes growth. Needs to be promoted to achieve this objective, use of seasonal, local, low-cost and abundantly available raw food ingredients having high nutrition and functional properties like millets, green gram and dairy ingredients should be advocated.

Therefore, the present study was thus undertaken to formulate six ready-to-use supplementary foods using three processing techniques: cabinet drying, drum drying and spray drying methods for young children (1-3 years) is facilitated the standardization of an optimized nutrition supplementary food.

Materials and Methods

Finger millet variety [CO (Ra) 14] and little millet variety [CO (samai) 4] was procured from the Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. Green gram, skim milk powder and sugar was purchased from the local market of Madurai, Tamil Nadu.

Malting of millets

Finger millet, little millet and green gram were malted as per the method suggested by Mamiro *et al.,* (2001) and Subba Rao (2001) with slight modification.

Processing of ingredients for cabinet drying

The sprouted millets and green gram were dried at 60°C for 8 - 12 hours and devegetated by abrasion to remove the husk and sprouts to obtain green malt. The green malt from finger millet, little millet and green gram was kilned by heat treatment at 65-70°C pulverized and sieved (BS 60 mesh sieve) to obtain malted flour.

Processing of ingredients for drum drying

Finger millet, little millet and green gram were drum dried as per the method suggested by Rodriguez and Vasseur (1996) and Mazaher *et al.,* (2009) with slight modification. A laboratory double drum dryer (Escher-Wyss, Germany) was utilized in this experiment.

Germinated millet kernels *viz.,* finger millet and little millet and green gram were washed and soaked in water for 30 minutes. The soaked grains were ground with water in the proportion of 1:1 (millet:water).

The prepared millet slurry, containing 450 g of starch per litre of water of the moist material was uniformly applied in a thin layer (0.5 mm - 2 mm) onto the outer drum surface to produce thin continuous sheets with about 5 per cent residual moisture.

Most of the moisture is removed when the temperature reaches the boiling point water. The dried sheets on the outer surface of the drum were collected and crumbled by blades, pulverized, passed through 60 BS mesh sieve, and stored in polyethylene covers.

Processing of ingredients for spray drying

Malted millets and green gram were spray dried as per the method suggested by Caparino *et al.,* (2012) with slight modification.

The germinated millet kernels *viz.,* finger millet and little millet and green gram were washed and soaked in water for 30 minutes. The soaked grains were ground with water in the proportion of 1:2 (millet:water) and filtered through a cheesecloth to remove the coarse particles. To the filtrate containing solid content of 200-230 g/ 1000 ml, maltodextrin with a dextrose equivalent (DE) of 9-11 was added directly to the millet slurry with magnetic stirring until a homogeneous solution was obtained.

The mixture was kept at room temperature for 30 minutes to dissolve the maltodextrin. After 30 minutes, the mixture was filtered by muslin cloth and the filtrate was kept ready for spray drying. Before starting the experiment, the dryer was conditioned for 20 minutes by pumping de-ionized water through the atomizer with the dryer inlet and outlet temperature set at 180°C and 80°C respectively. The filtrate was fed in the spray dryer with an inlet drying air temperature (180°C) and the feed rate as 3-5 ml/min. The spray dried materials, was immediately packed in aluminium cover.

Standardization of supplementary mix

Development of supplementary foods based on locally available cereals and legumes has been suggested by the Integrated Child Development Scheme (ICDS) and Food and Agriculture Organization (FAO) to combat malnutrition among children of low socio-economic groups (Imtiaz *et al.,* 2011).

Six formulations of supplementary mix (T_{1C}, T_{2C}, T_{1D}, T_{2D}, T_{1S} and T_{2S}) was prepared from the cabinet dried, drum dried and spray dried samples of malted minor millet flour to which malted green gram flour, skimmed milk powder and sugar were mixed in different proportions considering nutrient and caloric values of each ingredient in order to meet the nutrient requirement of young children (1-3 years) according to the recommendations and guide lines given by the ICMR (2012) and Codex Standard for Processed Cereal-Based Foods for Infants and Young Children (CODEX STAN 74-1981, rev. 2006) to reach equal energetic value (400 Kcal/100g).

The protein energy ratio of the mix was more than 15 per cent and the formulated 100 g portion of each supplementary mix enables to provide 1/3 of the daily energy and carbohydrate requirement, 2/3 of the daily protein requirement and ¼ of the daily fat requirements of growing children (Table 1).

Where,

T_{1C}, T_{1D} and T_{1S} - Finger millet, green gram, milk powder and sugar *i.e.* 50:20:20:10

T_{2C}, T_{2D} and T_{2S} - Little millet, green gram, milk powder and sugar *i.e.* 50:20:20:10

Chemical analysis

All samples were analyzed for moisture, protein, fat, fiber, total carbohydrate and ash. The mineral contents *viz.*, calcium, magnesium, sodium, potassium, zinc and iron were determined by Atomic Absorption Spectroscopy according to the procedures outlined by AOAC (2000).

Growth experiment

Wistar albino rats of 25 - 28 days of age (24 Nos) each weighing approximately 100-150 g was selected for the study. They were housed in stainless steel rat cages and acclimatized for 2 days with free access to food and water. After two days, during the initiation of the experiment, the weight of the rats were recorded and the rats were divided into 8 groups (six experimental groups + one reference group + one control group) of 3 rats each group. Details of experimental groups and experimental diets (standardized diet - millet mix, standard diet and protein free diet) are furnished in Tables 2 and 3 respectively.

A weighed diet comprising of the standardized health mix formulations and the control diet inclusive of *adlibitum* of water was given throughout the experimental period and unconsumed food was collected, dried and weighed. The body weight of the animals and unconsumed foods were measured on daily basis for 28 days of feeding trial. The period of the study for protein efficiency ratio (PER) and food efficiency ratio (FER) was calculated and recorded for 28 days by the method outlined by Chapman *et al.,* (2001) and Laminu *et al.,* (2014).

Nitrogen balance studies

After 28 days of growth study (PER and FER) the nitrogen balance study was continued for 9 days which included a four day adjustment and five day nitrogen balance study for the above experimental group of animals (six experimental groups + one reference group + one control group). For the nitrogen balance study, in addition to the existing experimental group of animals, another group of rats of the same weight and age were selected and fed on protein-free basal diet to calculate the endogenous urinary nitrogen (EUN) and metabolic faecal nitrogen (MFN) losses. A weighed diet and *ad libitum* water were given throughout the experimental period and unconsumed food was collected, dried and weighed. There was a preliminary feeding period of four days followed by a balance period of five days during which complete collection of faeces and urine were performed for each group. For all the 9 days, urine and faeces were collected for determination of nitrogen content. The data was used to calculate digestibility coefficient (DC) and biological value (BV), net protein utilization (NPU) and net available protein (NAP) by method outlined by Laminu *et al.,* (2014) and Onweluzo and Nwabugwu (2009).

Statistical Analysis

The data on the quality characteristics of the millet based health mix were subjected to statistical analysis to study the impact of different treatments and storage period on the quality of the stored products using Indian NARS Statistical Computing Portal using the link http://stat.iasri.res.in/sscnarsportal/main.do hosted by ICAR-Indian Agricultural Statistics Research Institute. The means were compared using LSD at 1 per cent. The data related to the animal experiments were replicated three times and all the values were analysed using variance (ANOVA) followed by Newman-Keul's multiple range tests.

Results and Discussion

The results of the present study in terms of chemical composition such as moisture, protein, fat, fiber, ash, carbohydrate, mineral contents (*i.e*. calcium, magnesium, sodium, potassium, zinc and iron) and animal experiments namely Protein Efficiency Ratio (PER), Food Efficiency Ratio (FER), True Protein Digestibility (TPD), Biological Value (BV), Net Protein Utilization (NPU) and Net Available Protein (NAP) of the formulated supplementary mix *viz*., T_{1C}, T_{2C}, T_{1D}, T_{2D}, T_{1S} and T_{2S} as well as relevant discussions have been presented under following sub heads.

Nutritional composition

The data pertaining to the nutrient content *i.e.* moisture, crude protein, crude fat, crude fiber, ash and total carbohydrate of six different health mix (T_{1C}, T_{2C}, T_{1D}, T_{2D}, T_{1S} and T_{2S}) formulated from different drying methods namely cabinet dried, drum dried and spray dried were determined and the details are presented in Table 3.

Among the three drying methods, the moisture content was found to be significantly ($P<0.01$) lower in spray dried formulation T_{2S} (4.25 %) followed by T_{1S} (4.37 %) and highest in cabinet dried formulation T_{2C} (8.57 %). Moisture content of all food products was within the range recommended (<10%) for proper storage of dehydrated foodstuff (CODEX, 2006). Germinated popcorn-African locust bean blend and cerelac are reported to have high moisture contents of 10.2% and 11.3%, respectively (Ijarotimi and Keshinro, 2013). High moisture levels (above 10%) accelerate spoilage by promoting microbial activity and chemical reactions that reduces product shelf life. Levels of moisture in formulated mixes were comparable to ogi and other infant formulas (Ijarotimi and Keshinro, 2013). Sufficient drying of raw materials is critical for proper storage of supplementary foods.

The amount of protein was high in T_{2C} (26.35 %) prepared using cabinet drying method was higher which was on par with T_{1C} (26.04 %) compared to other formulations. Protein content of standardized mix were higher than the minimum recommended levels of 14 % (N X 6.25) by CODEX (2006) for management of malnutrition. Accordingly, protein content of the supplementary food products provided for recommended daily intakes (RDI) (26 g/1000 kcal, 10.4 % protein energy) for children of 6 to 59 months of age who are moderately malnourished (Golden, 2009). Protein recommendation by FAO/WHO and Institute of Medicine (IOM) for normal children is set at 21 g/1000 kcal. A diet containing 24 g of protein per 1000 kcal has also been recommended (Golden, 2009) for recovery of children suffering from moderate malnutrition.

Among the drying methods, the cabinet (T_{1C} and T_{2C}) and drum dried (T_{1D} and T_{2D}) formulations were found to be effective in better retention of fat content i.e., above 4 per cent and low fat content was found in T_{2S} (2.14 %). A child suffering from malnutrition has high-energy needs requiring a diet of sufficient fat content. Fat is also needed in the absorption of vitamins A and E (Michaelsen, 2009). Vitamins A and E are vital for immediate recovery from acute malnutrition and to reduce disease incidences in children. Milk-based products have been demonstrated to boost children's growth and immunity associated with fat-soluble vitamins (Diop el *et al.,* 2003). It is desirable that supplementary diets contain high fat to provide the required energy to the malnourished child. Oduro *et al.,* (2007) reported that food sample with high fat content is more liable to spoilage than one with a lower fat content.

Spray dried formulations T_{1S} and T_{2S} contained low crude fiber (0.86 and 0.83 %, respectively). The cabinet dried formulation T_{2C} (6.35 %) had higher crude fiber. Dietary fiber plays vital physiological and biochemical roles in digestion. Particularly, soluble fiber imparts prebiotic properties while insoluble fiber prevents constipation. According to Michaelsen (2009), constipation is not a major issue in malnourished children. Based on extrapolation, a total dietary intake of 11g/1000 kcal is recommended in formulations of supplementary foods (Golden, 2009). A further reference intake suggested for children 3 years and above for dietary fiber intake is 5 g plus 1 g for each year of age (Dwyer, 1995). This range of dietary fiber intake is considered to be safe for normal laxation, and helps prevent future chronic illnesses. Based on above recommendations, amounts of dietary fiber in formulated mixes remain within healthy levels except spray dried formulations.

The ash content of the product gives an idea of the mineral content, although formulated supplementary mixes had low ash contents ranged between 2.63 to 2.95 per cent. The higher amount of carbohydrate content of the formulated supplementary mix (T_{1S}) was 68.54 g/100g followed by the formulation (T_{2S}) which contained 68.50 g/100g and (T_{1C}) contained lower content of 64.03 g/100g. The RDA of carbohydrate for young children is 95 g/day (IOM, 2005). So the formulated spray dried mixes had higher carbohydrate content and supplied approximately 72 per cent recommended carbohydrate for young children.

Mineral content

The mineral content such as calcium, magnesium, sodium, potassium, iron and zinc content of standardized health mix prepared by different drying methods *viz.,* cabinet drying, drum drying and spray drying was depicted in Table 4.

The level of calcium in the formulation T_{1C} prepared by cabinet drier, exhibited highest calcium level (1272.13 mg/100g) followed by drum dried T_{1D} and T_{1S} (1248.63 and 1205.83 mg/100g, respectively) and spray dried formulations (1082.4 mg/100 g).

It is recommended that, diets should contain adequate amounts of calcium to avoid osteoporosis. In developing countries, even for cases of normal children, calcium levels are very low in most diets. It is necessary that diets have sufficient calcium for normal bone density to be restored and maintained. In addition, the calcium: phosphorous ratio should be maintained within the range of 0.7 to 1.3 for all children above 6 months of age. Golden (2009) has recommended levels of 840 mg/1000 kcal if the formulation is to be fortified and 600 mg/1000 kcal if it's based on only local foods. Levels of calcium in formulated health mixes were adequate for rehabilitating a malnourished child.

Among the drying methods, cabinet dried formulation T_{1C} showed significantly higher magnesium levels (74.26 mg/100 g) when compared to drum and spray dried formulations. All formulations met the recommended levels of 200 mg/1000 kcal (Golden, 2009). Magnesium is a growth nutrient and deficiency has a negative influence on growth since its deficiency interferes with protein utilization. Magnesium is particularly important for stunted children who need to grow.

Total sodium in the body, instead of decreasing, increases considerably during malnutrition. This increase stems from the reduction in potassium concentration resulting in an electrolyte imbalance. Accordingly, sodium pump slows down consequently increasing intracellular sodium content. For the formulations prepared using different drying methods, the level of sodium were recorded to be maximum in cabinet dried samples T_{1C} and T_{2C} (120.30 and 114.57 mg/100g, respectively) followed by spray dried T_{1S} and T_{2S} (109.60 and 102.37 mg/100g, respectively) and drum dried T_{1D} and T_{2D} (99.70 and 101.27 mg/100g, respectively) samples.

Diets that contain high sodium concentrations would then be detrimental arising from toxicity. Accordingly, requirements for moderately malnourished children have been set at a far lower level than those for normal children. Levels of sodium in formulated mix do not exceed the maximum recommended amount of 550 mg/1000 kcal set by Golden (2009).

Among the drying methods, the potassium level was maximum in cabinet dried formulations T_{1C} and T_{2C} (283.27 and 264.47 mg/100g, respectively) followed by spray dried T_{1S} and T_{2S} and drum dried T_{1D} and T_{2D} formulations. Depletion of potassium takes place in all malnourished children. Supplementary diets should contain sufficient potassium to maintain a renal excretion of 27 mg/kg /day and a fecal excretion of 39 mg/kg /day. Based on these considerations, potassium amount in formulated mix could repair tissue deficit of potassium in about three days for children.

The amount of iron and zinc present in the formulated supplementary mix *viz*., T_{1C}, T_{2C}, T_{1D}, T_{2D}, T_{1S} and T_{2S} was 5.61, 5.14, 5.36, 5.29, 5.61, 5.91, 2.08, 2.62, 2.08, 2.19, 2.75 and 2.84 respectively. The RDA of iron for young children is 12 mg/100g (ICMR, 2012). Thus the high iron content of formulated mix can meet the 50 per cent of iron respectively for young children. Statistical analysis of the data revealed significant difference between treatments. In most malnourished children, storage levels of iron increases and may not decrease even in cases of severe anaemia.

Table.1 Formulation of ingredients for supplementary mix

Ingredients	Standardized supplementary mix					
	Cabinet dried		Drum dried		Spray dried	
	T_{1C}	T_{2C}	T_{1D}	T_{2D}	T_{1S}	T_{2S}
Finger millet (g)	50	-	50	-	50	-
Little millet (g)	-	50	-	50	-	50
Green gram (g)	20	20	20	20	20	20
Milk powder (g)	20	20	20	20	20	20
Sugar (g)	10	10	10	10	10	10
Total (g)	100	100	100	100	100	100

Table.2 Experimental, standard and non-protein diet for protein quality studies

Ingredients (g)	Standardized diet - millet mix						Standard diet	Protein free diet
	Cabinet dried		Drum dried		Spray dried		Reference group	
	T_{1C}	T_{2C}	T_{1D}	T_{2D}	T_{1S}	T_{2S}	T_1	T_0
Finger millet	50	-	50	-	50	-	-	-
Little millet	-	50	-	50	-	50	-	-
Green gram	20	20	20	20	20	20	-	-
Milk powder	20	20	20	20	20	20	-	-
Sugar	10	10	10	10	10	10	-	-
Corn starch	-	-	-	-	-	-	52	80
Milk powder	-	-	-	-	-	-	28	-
Corn oil	-	-	-	-	-	-	10	10
Cellulose	-	-	-	-	-	-	5	5
Mineral mix	-	-	-	-	-	-	4	4
Vitamin mix	-	-	-	-	-	-	1	1
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Protein (%)	18.52	18.16	17.4	17.9	14.78	15.4	10	-
Carbohydrate (g)	72.10	75	68	68.4	79.2	79.5	54	72
Energy (Kcal)	352	357	343	349	374	379	315	380

Control group (normal food)

Table.3 Nutritional composition of the supplementary mixes

Standardized mix	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
T_{1C}	8.06^{a}	26.04^{a}	4.05^{fg}	6.27^{a}	2.95^{a}	64.03^{a}
T_{2C}	8.57^{b}	26.35^{a}	4.83^{a}	6.35^{b}	2.94^{a}	64.09^{b}
T_{1D}	5.85^{c}	25.43^{c}	4.06^{efg}	6.03^{c}	2.95^{a}	64.53^{c}
T_{2D}	5.72^{d}	25.91^{b}	4.07^{e}	6.02^{c}	2.92^{b}	65.07^{d}
T_{1S}	4.37^{e}	23.61^{e}	2.35^{l}	0.86^{d}	2.63^{d}	68.54^{d}
T_{2S}	4.25^{f}	24.84^{d}	2.14^{n}	0.83^{e}	2.67^{c}	68.50^{d}

Note: Values in the same column with different superscripts are significantly different at (P<0.01)

Table.4 Mineral content of the supplementary mixes

Standardized mix	Calcium	Magnesium	Sodium	Potassium	Iron	Zinc
T_{1C}	1272.13[a]	74.26[a]	120.30[a]	283.27[a]	5.61[g]	2.08[l]
T_{2C}	1170.43[e]	69.94[c]	114.57[c]	264.47[d]	5.14[p]	2.62[f]
T_{1D}	1248.63[b]	70.13[b]	99.70[l]	254.17[h]	5.36[l]	2.08[l]
T_{2D}	1109.67[k]	64.78[g]	101.27[k]	253.57[i]	5.29[m]	2.19[ij]
T_{1S}	1205.83[c]	69.17[d]	109.60[d]	259.30[f]	5.61[g]	2.75[c]
T_{2S}	1133.23[i]	64.12[i]	102.37[i]	235.83[p]	5.91[a]	2.84[b]

Note: Values in the same column with different superscripts are significantly different at (P<0.01)

Table.5 Growth and nitrogen balance study of the standardized health mix

Particular	Experimental groups							
	T_0	T_R	T_{1C}	T_{2C}	T_{1D}	T_{2D}	T_{1S}	T_{2S}
Protein Efficiency Ratio (PER)	1.37	1.55	1.69	1.71	1.70	1.71	1.73	1.72
Food Efficiency Ratio (FER)	0.18	0.20	0.23	0.24	0.24	0.24	0.24	0.24
True Protein Digestibility (%)	80.32	82.45	85.61	86.05	87.92	88.25	90.16	90.83
Biological Value (%)	73.82	75.18	77.23	77.59	79.21	79.05	81.52	81.46
Net Protein Utilization (%)	59.27	61.98	66.11	66.76	69.64	69.76	73.49	73.99
Net Available Protein (%)	44.57	50.26	57.18	57.88	61.80	62.32	66.28	67.03

T_0 - Control group and T_R - Reference group

Iron nutrient density should therefore not be high but rather modest in diets formulated for malnourished children. Diets high in iron have been found to increase mortality rates. Iron supplements may therefore be recommended for other functions other than that of anaemia. It is a vital part of hemoglobin required in sizeable amounts in children (Michaelsen, 2009). Zinc helps in preventing diarrhea in malnourished children. It is also essential for growth, synthesis and maintenance of lean body mass (Michaelsen, 2009).

Growth and nitrogen balance studies

Table 6: presents the data related to growth and nitrogen balance study of the standardized health mix. The PER of a food reflects its biological value because the weight gain measured in PER are dependent on the incorporation of food protein into body tissue. The FER is measured as a function of gain in body weight and food consumed. Foods with high FER tend to add to weight gain while low FER are prone to be used as energy rather than stored as body weight (Bryrd-Brdbenner *et al.,* 2009).

The Protein Efficiency Ratio (PER) and Food Efficiency Ratio (FER) were the highest for those rats on the spray dried formulation (T_{1S}) with highest values of 1.73 and 0.24 respectively which was closely followed by T_{2S} (1.72 and 0.24 respectively). While lowest PER (1.37) and FER (0.18) were observed in control group (T_0). The formulated health mix blends had high PER and FER comparable to that of control and reference group. The high PER and FER exhibited by the health mix developed from spray dried millet formulations may be augmented to the increase in nutrient density of the spray dried formulation which may have contributed to the high PER and FER values.

Mohammed *et al.,* (2013) developed highly nutritive instant weaning foods by using locally available cereals, skim milk powder, vitamin premix and sugar and reported that higher Protein Efficiency Ratio (2.11) and Food Efficiency Ratio (0.20) for the developed weaning food on comparison with imported commercial weaning foods.

The group of rats that were fed spray dried formulation (T_{1S} and T_{2S}) had the highest percentage of True Protein Digestibility (90.16 and 90.83 % respectively), Biological Value (81.52 and 81.46 % respectively), Net Protein Utilization (73.49 and 73.99 respectively) and Net Available Protein (66.28 and 67.03 respectively) which was closely followed by drum dried formulation (T_{2D}) which recorded slightly lower values for TPD (88.25 %), BV (79.05 %), NPU (69.76 %) and NAP (62.32 %) and lowest in cabinet dried formulation (T_{1D}

and T_{2D}). The control (T_0) and reference group (T_R) which were fed with normal food and 10 per cent protein diet had the lowest percentage of True Protein Digestibility (80.32 and 82.45 % respectively), Biological Value (73.82 and 75.18 % respectively), Net Protein Utilization (59.27 and 61.98 respectively) and Net Available Protein (44.57 and 50.26 respectively). Significant difference was observed between the treatments.

The results indicated that the group of rats which were fed the formulated health mix had lower faecal and urinary nitrogen loss and higher retention of nitrogen. This could be as a result of higher protein content of health mix. On the other hand, the control and reference group had higher faecal and urinary nitrogen loss and lower retention of nitrogen. More nitrogen is retained when a foods amino acid pattern closely matches the body demand for various amino acids (Bryrd-Brdbenner *et al.,* 2009). Faecal nitrogen affects digestibility and high faecal nitrogen losses indicate low nitrogen digestibility and utilization (Onweluzo and Nwabugwu, 2009).

Akeredolu *et al.,* (2005) formulated supplementary food from pearl millet with nut flour and compared with soy-ogi food. The developed millet food had highest value of PER, BV, NPU and TD values which was much higher than soy-ogi. It was therefore, concluded that the millet based formulations had better protein quality than the soy-ogi. Laminu *et al.,* (2014) formulated weaning foods using pearl millet, cowpea, ground nut and wheat and protein quality was evaluated by nitrogen balance study and it was found that True Protein Digestibility, Biological Value, Net Protein Utilization were 97.44, 82.81 and 80.69 per cent respectively.

Conclusions

The supplementary mix formulated in the present study was based on locally available low cost food materials that can also be affordable by people of low economic status. The developed mix has promising nutritional attributes. They contain reasonable quantities of most nutrients, significantly increased levels of protein, iron, calcium and potassium in accordance with BIS standards. It can be stored for a period of six to twelve months with better sensory scores. Spray dried formulation recorded good nutrient profile which was closely related to drum and cabinet dried formulations. Spray dried formulations showed highest weight gain, food efficiency ratio, true protein digestibility, biological value, net protein utilization and net available protein on comparison to the control group and the other experimental groups fed with drum dried and cabinet dried supplementary mix formulations. Based on the results, it can be suggested that fortification of legumes into the conventional cereal based supplementary foods and diluting in milk or yoghurt instead of liquid, results in a product with extreme nutritional quality, cost effective and could be a possible and effective tool in order to overcome the malnutrition among children in the developing countries.

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