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Evaluation of Chemical Composition Protein Quality and Amino Acid Scoring WHO/FAO Standards of Functional Cereals Oat Pearl Millet Sorghum and Finger Millet

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Abstract

The study was done on the characterization of Millets for their chemical and amino acid composition, total amino acid profile and amino acid scoring. The analyzed millet grains depicted moisture content less than 10 % that ensured higher storage stability. Pearl millet and sorghum had the most desirable amino acid composition. Non-essential amino acid content dominated the overall amino acid profile in analyzed pearl millet, finger millet and sorghum. Pearl millet and sorghum proteins was found to have an Essential amino acid index (EAAI) value of greater than 90 and thus are considered as good quality proteins. Sorghum was found to contain isoleucine as its limiting amino acid. The analyzed millets were found to contain higher amounts of tyrosine than phenylalanine, thus the consumptions of these cereals could be beneficial for those suffering from phenylketonuria. Oats and Finger millet were found to contain lowest concentration of sulphur containing essential amino acids cysteine and methionine.

Keywords: Millets; Chemical Composition; Essential Amino Acid Index; Biological Value; Protein Efficiency Ratio

Abbreviations: EAAI: Essential Amino Acid Index; PER: Protein Efficiency Ratios; ANOVA: Analyzed by Analysis of Variance; BV: Biological Value.

Introduction

Millets can secure India's food and farming in future because of their amazing nutritional properties. Each one of the millets is three to five times nutritionally superior in comparison to widely promoted rice and wheat in terms of macro as well micro nutrients. Moreover, millets are easy to digest and soothing as they are not gas former. In fact, millets are considered to be the least allergenic crops and are rich sources of proteins, calcium, phosphorus, iron. These crops are drought-resistant and the 6th cereal crop in terms of world agriculture production. Also, millets are resistant to pests and diseases, short growing season, and productivity under drought conditions, compared to major cereals. The total production of millet grains in the world was about 762712 metric tons and India is

the top producer with an annual production of 334500 tons (43.85%). Therefore, millet grains are now receiving specific attention from many developing countries. Finger millet (Eleusine coracana), also known as ragi is a good source of carbohydrate, protein, dietary fiber and minerals, and an important staple food for people under low socio-economic group and those suffering from metabolic disorders like diabetes and obesity. In India, sorghum is one of the staple food crops of many States, and is consumed by majority of people particularly living in the non-irrigated dry land areas with low rainfall.

It is cultivated in the semi-arid tropical regions. Sorghum grain is food of the economically weaker sections. It is mainly consumed in the form of unleavened bread (roti) and to some extent as popped grains. This crop uses less water per unit of forage production, tolerates both lower and higher soil pH and higher aluminum concentration.

The quality of proteins mainly depends on its amino acid composition especially essential amino acids and the different millets differed in their essential amino acid profiles. The protein content and its quality can be improved by breeding and genetic engineering techniques. It can also be increased by fermentation methods. The proteins of millets are gluten free and are non allergenic, hence their consumption decreases triglycerides and C-reactive proteins that may prove beneficial in preventing cardiovascular disease. The protein in millet complements efficiently with lysine rich vegetables, leguminous crops, and animal proteins, thus helps in forming nutritionally balanced composites of high biological value. The cereals chosen for experimental work are grown in abundance and are consumed by the population of Himalayan belt in Himachal Pradesh (India) in several processed forms. Therefore, the present research was conducted to preserve these landraces and to make aware the people regarding their functional properties. Keeping into consideration the nutritional values of millets the present research is to evaluate the protein quality comprising of amino acid profile, essential amino acid index, nutritional evaluation, protein efficiency ratio and biological value of oat, pearl millet, sorghum and finger millet.

Material and Methods

Procurement of Raw Material

The millets under study were procured from the university farm (CSKHPKV, Palampur, Himachal Pradesh). The oat cultivar (Palanpur-1) was chosen for research due to its maximum cultivation in state. The chemicals and reagents needed for analysis of proximate composition were purchased from Sigma-Aldrich.

Preparation of Samples

The procured samples were cleaned manually for removing adhering dirt, dust and foreign particles. The grains were ground into fine flour by pilot scale grinding mill (Agrosa Pvt. Ltd., India) to a specific particle size i.e. with fifty two mesh sieve, stored in airtight food grade containers and stored at ambient temperature for further use. All the analysis was carried out in triplicates to reduce any error [1-4].

Chemical Composition Estimation

The water, protein, fat and ash contents of the selected cereals were determined by following the standard procedures of AACC (2000). Crude fiber constituents were determined by following the protocol of Van Soest, et al. [5].

Amino Acid Analysis

Amino acid profiling was done by using High performance liquid chromatography. Samples was ground and passed through a sieve of 52 BSS pore size to get uniform sized particles of flour. Screw capped test tubes were taken for hydrolysis process. They were dipped in 0.1 M HCl for the whole night to avoid any sort of contamination. Each sample was accurately weighed at about 0.2 g with the help of analytical balance and was put into test tubes containing 12 ml of 6 M HCl.

Tubes were evacuated by nitrogen flushing and were capped immediately. Tubes containing samples and HCl were transferred in an oven for about 24 hours at 110oC for complete hydrolysis of test samples. Samples were taken out from the oven after specified time, cooled to room temperature, and dried to remove HCl. Samples were reconstituted again in 3 ml of 0.02 M HCl. Each one was filtered carefully through 0.22 µm filter paper to remove small sized contaminants prior to centrifugation at 3000 rpm for 10 minutes. The supernatant was derivatized and then filtered using a 0.45-µm PTFE membrane before injection in HPLC. HPLC instrument was equipped with auto injector, column compartment, fluorescent detector (G1315B), vacuum degasser, and quaternary pump. Separation was performed on Eclipse XDB C18 Column (ID 2.1 × 150 mm, 5 µ particle size) at 40°C. Peak monitoring was achieved on a fluorescent detector with excitation wavelength being λex =340 nm and emission being λem =450 nm.

Protein Quality Evaluation

Essential Amino Acid Index (EAAI): EAAI was calculated using the method as described by Oser [6], by using the ratio of relative Essential amino acids in the test protein as

compared to the respective values in whole egg protein [7].

$$EAAI = n\sqrt{\frac{Lys_a \times Tyr_a \times ..... \times His_a}{Lys_b \times Tyr_b \times ..... \times His_b}}$$

Where "a" is the amino acid in test sample and "b" is the amino acid in reference protein sample.

Nutritional Index Nutritional index was calculated as a function of Essential amino acid index and total protein as described by Ijarotimi [8].

$$Nutritional\ index\,(\%) = \frac{Essential\ amino\ acid\ index \times protein\ (\%)}{100}$$

Biological Value: Biological value was calculated according to the equation suggested by Oser [6].

Biological value=1.09×Essential amino acid index-11.7

Protein Efficiency Ratio: As per joint report of WHO/FAO (1991) expert's consultation, it was reviewed and suggested to replace the method of protein efficiency ratio assay using rat growth, and had been concluded unsatisfactory. Thus, protein efficiency ratios (PERs) on the basis of interaction between Leucine-proline, and Leucine-tyrosine were calculated using the modified regression equations as described by Alsymer [9].

PER-1= -0.684+0.456(leu)-0.047(pro)

PER-2= -0.468+0.454(leu)-0.105(tyr)

Amino acid score

Amino acid score (%) for infants (pre-school) and adult were calculated as the ratio of observed value of amino acid (g/100g of protein) to the reference pattern as provided by FAO/WHO [25].

Statistical Analysis: Experimental data was analyzed by analysis of variance (ANOVA) and Duncan's Multiple Range test in triplicate. All statistical analysis was performed using commercial statistical package SPSS (16.0, Chicago, IL, USA).

Result and Discussion

Chemical Composition of Selected Millet Grains

The millets under study were evaluated for different constituent's viz. moisture, ash, crude fat, crude fiber, protein and carbohydrates as displayed in Table 1. Estimation of moisture is widely used in testing the quality of food. The moisture content was found to be higher in pearl millet (9.53%) and lowest in sorghum (7.25%). As the dry matter in food materials is inversely related to the amount of moisture it contains and it is directly related to stability, eating quality, nutritive value and processing requirements. Moisture content has an essential role in determining the physical appearance and kernel morphology of cereal grains [10]. All of the analyzed millet grains depicted moisture content less than 10 per cent that ensured higher storage stability and overall quality of these cereals due to reduced chances of biochemical reactions and mold infestations [11].

Crop Parameters (%)	Oat	Pearl Millet	Sorghum	Finger Millet
Moisture	8.73±0.01^{b}	9.53±0.02^{a}	7.25±0.04^{d}	8.47±0.02^{c}
Ash	3.50±0.03^{a}	2.48±0.01^{b}	1.43±0.01^{c}	2.41±0.09^{b}
Crude Fat	4.95±0.03^{a}	4.93±0.03^{a}	2.67±0.01^{b}	2.00±0.05^{c}
Crude Fiber	5.34±0.03^{a}	2.70±0.02^{b}	2.35±0.04^{d}	3.63±0.02^{c}
Crude Protein	14.69±0.03^{a}	12.03±0.09^{b}	11.23±0.02^{d}	7.45±0.005^{c}
Carbohydrate	62.79±0.04^{d}	68.33±0.14^{c}	75.07±0.09^{b}	76.04±0.06^{a}

Table 1: Chemical composition of selected crops.
Values are expressed as mean ± standard deviation (n=3; p ≤ 0.05)
Values in a row with different small letters superscript are significantly different (p≤ 0.05)

Ash content gives an index to the mineral matter in food materials and was observed to vary from 1.43 to 3.5%. The presence of higher ash content in oats reflects the availability of more minerals among the selected cereal grains as reported earlier by Klava [12]. The decreased ash content in sorghum and millets could be attributed to processing of these cereals that lowers the mineral content of these cereals. The highest amount of crude fat in oats (4.95%) and pearl millet (4.93%) could be beneficial for using as animal feed due to its higher energy value along with good composition of fatty acids. But this high lipid content provides fewer benefits when used for human food formulations due to several processing problems like poor flavor and excessive browning of toasted products [13].

Oats contain a higher content of polar lipid than that of other cereals as much of the lipid fraction is contained within the endosperm of this particular cereal. The results of present

study for fat content are also close to the values reported by the Bilal, et al. [14] who reported 5.49 ±0.76 per cent fat content in oat. The protein content of the analyzed millets and oats varied from 7.45% to 14.69%, with oats having higher concentration of protein content. Oat proteins are considered cost effective having good nutritional value and differs in structural properties and distribution of protein fraction in comparison to other proteins of cereal grains [15]. Crude fat is the crude mixture of fat soluble materials present in samples whereas, crude fiber is the residue of plant materials remaining after solvent extraction followed by digestion with acid and alkali and the estimation of crude protein reflects that total nitrogenous and non nitrogenous protein present in the sample.

The crude fiber varies from 2.7% to 5.34% with sorghum having the least fiber content and oats having the highest fiber content. The polysaccharide β-glucans in oats are components of dietary fiber that are resistant to digestion and absorption in the small intestines and reduces the blood cholesterol and glucose levels in human body [16]. The carbohydrate content was found lowest in pearl millet having value of 68.33%, while as finger millet showed the highest content of 76.04%. Starch is the main carbohydrate present in finger millet and amylopectin constitutes about 80 to 85% of the finger millet starch [17].

Amino Acid Profiles of Selected Millets Crops (µg/100g)

The Protein quality of grains is attributed to the distribution pattern of protein fractions in their genetic makeup. Oats excelled in lysine and tyrosine. Sorghum was found to contain a limiting content of Lysine and a significant positive correlation was found between the protein in the grain and the Lysine content, which is antagonist with the findings of Deosthale, et al. [18].

Sr.No.	Amino acid (µg/100g)	Oat	Pearl Millet	Sorghum	Finger Millet	A
1	Histidine	670.00±0.03^{a}	1954.00±0.01^{c}	1965.00±0.17^{b}	3800.00±.03^{d}	1.50
2	Isolucine	3352.00±0.02^{b}	6742.00±0.08^{a}	679.00±0.13^{d}	729.00±0.04^{c}	3.00
3	Leucine	1777.00±0.08^{c}	10812.00±0.13^{b}	10911.00±0.0.14^{a}	1296.00±0.02^{d}	5.95
4	Lysine	1822.00±0.05^{a}	1682.00±0.15^{b}	148.00±0.02^{d}	1080.00±0.01^{c}	4.50
5	Methionine	720.00±0.02^{d}	2296.00 ±0.93^{b}	2320.00±.0.02^{a}	154.00±0.04^{c}	1.60
6	Phenylalanine alanine	580.00±0.17^{c}	3547.00±0.18^{b}	3769.00±0.80^{a}	341.00±0.40^{d}	-
7	Threonine	3021.00±0.03^{c}	6782.00±.0.02^{b}	6810.00±0.03^{a}	584.00±0.01^{d}	2.30
8	Tryptophan	672.00±0.02^{c}	1796.00±070^{b}	1863.00±040^{a}	157.00±0.40^{d}	0.60
9	Valine	2180.00±0.8^{c}	6452.00±0.55^{b}	6459.00±0.58^{a}	784.00±0.02^{d}	3.90
10	Alanine	1034.00±0.04^{c}	4967.00±0.01^{b}	5532.00±0.94^{a}	657.00±0.03^{d}	
11	Arginine	1288.00±0.45^{d}	3126.00±0.68^{b}	3215.00±0.78^{a}	1317.00±0.69^{c}	
12	Aspartic acid	4015.00±094^{a}	10607.00±0.49^{d}	10807.00±079^{c}	1889.00±0.49^{b}	
13	Asparagine	ND	ND	ND	ND	
14	Cystine	790.00±0.87^{c}	2967.00±0.02^{b}	3108.00±0.04^{a}	148.00±0.03^{d}	
15	Glutamic acid	5072.00±0.02^{c}	19792.00±0.39^{b}	20272.00±0.39^{a}	2621.00±0.04^{d}	
16	Glutamine	ND	ND	ND	ND	
17	Glycin	795.00±0.78^{d}	2687.00±0.69^{b}	2655.00±0.93^{c}	6321.00±0.56^{a}	
18	Proline	1290.00±0.02^{c}	5866.00±0.08^{b}	5987.00±0.05^{a}	684.00±0.49^{d}	
19	Serine	2092.00±0.05^{c}	5245.00±0.04^{b}	5320.00±0.75^{a}	839.00±0.69^{d}	
20	Tyrosine	12900.00±0.01^{a}	3540.00±0.05^{c}	3547.00±0.89^{b}	572.00±0.03^{d}	
Total		32460.00	100860.00	95367.00	23973.00	

Table 2: Amino acid profile of oat, pearl millet, sorghum and finger millet.
Values are expressed as mean ± standard deviation (n=3; $p \leq 0.05$) Values in a row with different small letters superscript are significantly different ($p \leq 0.05$). A-Minimal levels of essential amino acids required by adult humans (FAO, 2007) ND: Not Detected.

Oat and pearl millet was found to contain an appropriate proportion of lysine (1822 and 1682 µg/100g), that is an essential amino acid involved in protein genesis, cross linking of collagen peptides and carnitine production. Thus the consumption of these cereals could prove effective in treatment of diseases including anaemia, impaired fatty acid metabolism and defective connective tissue Eyre, et al. [26]. Pearl millet and sorghum had the most desirable amino acid composition among the analyzed cereals (Table 2).

Among these three BCAAs pearl millet was found to contain the maximum content of isolucine (6742 µg/100g), while as Leucine and Valine was abundant in oat cereal and sorghum. Leucine is required for synthesis of muscle protein and hemoglobin formation whereas Lysine enhances the growth and repairmen of tissues. Threonine along with sulfur containing amino acids helps to retain positive nitrogen balance in body that is essential proper muscular growth and reduction in unwanted muscle contractions [16]. Threonine content was found highest in pearl millet and sorghum, while as finger millet contained the lowest content (584 µg/100g). Aromatic amino acids phenylalanine, tryptophan and tyrosine are produced at a large scale for their multiple applications in food industry. The non essential amino acid tyrosine is synthesized from an essential amino acid phenylalanine by using an enzyme phenylalanine hydroxylase. The deficiency of phenylalanine hydroxylase causes a buildup of phenylalanine in the body and creates a disorder phenylketonuria [19].

Phenylalanine is also used as a nutritional supplement for its analgesic and antidepressant effects (27). The analyzed millets were found to contain higher amounts of tyrosine than phenylalanine, thus the consumptions of these cereals could be beneficial for those suffering from phenylketonuria. Tryptophan is an essential aromatic amino acid required for normal growth of infants and for maintaining nitrogen balance in adults [20]. Sorghum and pearl millet was found to contain the highest amount of tryptophan with values 1863 µg/100g and 1796 µg/100g respectively. Tryptophan is also used as feed additive and in formulation of several foods, pharmaceutical and cosmetic products. Among the conditionally essential amino acids Pearl millet and sorghum was found to have higher content of arginine, cysteine, and proline, while as finger millets and oats were found to possess higher amounts of glycin (6321 µg/100g) and tyrosine (12900 µg/100g).

Thus these cereals might be useful for supplementation of infant foods and patients with suffering from severe catabolic problems (Dietary Reference Intakes, 2014). Oats and Finger millet were found to contain the lowest concentration of sulphur containing essential amino acids cysteine and methionine. The amount of each amino acids had been reported to be determined be the percentage of nitrogen in them and this nitrogen content had been found to depict a negative correlation with methionine, cystine and tryptophan [21].

Total Amino Acid Profile

The Amino acid profiling was done by calculations from the concentration of amino acids in the analyzed cereals as given in Table 3. The total percentage of essential amino acids, non-essential amino acids, aromatic amino acids, acidic and basic amino acids was calculated. BCAAs was also calculated from the ratio of leucine to isoleucine and the reported values of each parameter was compared with each other in the given samples to represent the generalized view about assessment of their protein qualities. Non-essential amino acid content dominated over total essential amino acids in analyzed pearl millet, finger millet and sorghum, while the total essential amino acid content was found highest in oats (85.32%).

	Oat	Pearl Millet	Sorghum	Finger Millet
Total essential amino acids (%)	85.32±0.15^{a}	43.27±0.03^{b}	36.18±0.12^{c}	23.76±0.03^{d}
Total non essential amino acids (%)	14.68±0.05^{d}	56.73±0.05^{c}	63.82±0.01^{b}	76.24±0.12^{a}
Total acidic amino acids (%)	27.99±0.03^{c}	30.14±0.14^{b}	32.59±0.05^{a}	18.81±0.15^{d}
Total basic amino acids (%)	11.64±0.12^{b}	6.70±0.03^{c}	5.58±0.03^{d}	25.85±0.03^{a}
Total aromatic amino acids (%)	43.60±0.05^{a}	8.81±0.12^{c}	9.62±0.10^{b}	4.46±0.05^{d}
Leucine/Isoleucine ratio (BCAA)	0.53±0.12^{d}	1.60±0.05^{c}	16.06±0.15^{a}	1.78±0.02^{b}

Table 3: Total amino acid profile of Oat, Pearl millet, Sorghum and Finger millet.
Values are expressed as mean ± standard deviation (n=3; $p \leq 0.05$)
Values in a row with different small letters superscript are significantly different ($p \leq 0.05$).

Thus oats could be used in supplementation and formulation of weaning and healthy protein rich diets. From the calculated values, it was found that the total acidic amino acids was higher in oats, pearl millet and sorghum, while as

finger millet was observed to have higher content of basic amino acids. The calculated value of Isoleucine to leucine ratio (BCAA) was found higher in sorghum (16.06) and lowest in oat (0.53). Branched chained amino acids are mainly used for muscle tissues buildup due to role in promoting protein synthesis and glucose metabolism [22]. BCAA is widely used by athletes to prevent degradation of muscle proteins and for building endurance. Leucine accelerates the synthesis of muscle proteins and isoleucine helps in glucose uptake by cells and provides endurance. With respect to the concentration of aromatic amino acids, oats were found to contain the highest percentage (43.60%) and the lowest content was shown by finger millet with calculated value of 4.46 %.

The aromatic amino acid serves as a precursor for synthesis of neurotransmitters serotonin, noradrenaline and dopamine that are essential for normal functioning of brain [23]. These also act as precursors for synthesis of variety of secondary metabolites responsible for formation of biological polymers, drugs, hormones, melanin and phenylpropanoids.

Amino Acid Based Nutritional Profile of Selected Millets

Proteins are considered of good quality when its essential amino acid index (EAAI) value is above 90% and is useful when its value ranged between 70-80%. If the EAAI is below 70%, then the food nutritional quality is considered inadequate [24; 6]. Pearl millet and sorghum proteins was found to have an EAAI value of greater than 90 and thus are considered as good quality proteins Table 4. Among the analyzed cereal only finger millet was found to have the least value of EAAI (20.42). Besides the amino acid composition, the quality of protein can be visualized with respect to its efficiency of utilizing it in terms of Biological value and PER. The biological value of nutritionally rich foods has been found to vary between 70 to 100%. Based on this criterion, the biological value of pearl millet and sorghum was found to be better and the lowest value was found in finger millet [24]. The higher biological values of oat, pearl millet and finger millet (>50%) gives an indication that maximum portion of absorbed amino acids from the food is retained and becomes incorporated into the proteins of an organisms body.

	Oat	Pearl Millet	Sorghum	Finger Millet
Essential amino acid index (EAAI)	68.76±0.05^{c}	162.21±0.03^{a}	97.27±0.05^{b}	20.42±0.12^{d}
Biological value (BV)	63.25±0.01^{c}	165.11±0.12^{a}	94.32±0.03^{b}	10.56±0.10^{d}
Nutritional index	10.10±0.12^{c}	19.51±0.15^{b}	10.92±0.01^{a}	1.52±0.03^{d}
PER-1	789.00±0.15^{b}	216.55±0.11^{d}	4627.88±0.05^{a}	550.37±0.15^{c}
PER-2	548.21±0.05^{c}	4536.48±0.01^{b}	4580.69±0.14^{a}	527.85±0.11^{d}

Table 4: Comparative amino acid based nutritional profile of Oat, Pearl millet, Sorghum and Finger millet.

Values are expressed as mean ± standard deviation (n=3; $p \leq 0.05$) Values in a row with different small letters superscript are significantly different ($p \leq 0.05$). Nutritional index being a quality characteristics in proteins depicting the effeiciency of human body to metabolise amino acids was found highest in pearl millet (19.51) followed by sorghum and oats. The lowest nutritional index in finger millet (1.52) could be attributed to least percentage of total essential amino acids along with crude proteins [25]. Protein efficiency ratios calculated on the basis of interaction between Leucine-proline, and Leucine-tyrosine gives a measurement of the weight gain by an organism to its consumption of a particular protein during the test period. Both PER-1 and PER-2 was found highest in sorghum and finger millet was found to depict the lowest value of 550.37 and 527.85 for both these ratios. The PER values is an essential tool to compare the food values of different sources of protein. Essential amino acid index is the geometrical mean of the ratio of all the essential amino acids in the analyzed protein relative to their content with a reference protein like whole egg [6].

Amino Acid Scoring of Millet Grains

Amino acid scoring gives the measurement of the efficiency of protein and amino acid requirement of a person. Amino acid score comprises the best estimates of amino acid requirements for humans. The lowest amino acid score for the indispensable amino acids in a protein depicts the most limiting amino acid that would give the first approximation of its efficiency of utilization by children [26]. Amino acid scoring for both infant and adult was determined with respect to the reference values provided by FAO/WHO [25] (Table 5). Phenylalanine + tyrosine were the limiting amino acid in oats and finger millet, whereas lysine was the limiting amino acid in pearl millet. Sorghum was found to contain isoleucine as its limiting amino acid. The lowest score obtained for any amino acid in a protein which is the "most limiting amino acid", indicated its first approximation of efficiency of utilization by children, but it underestimate the quality of the protein for adults [27].

Amino Acid Score (for infants/pre school-1-2 yrs)	FAO/WHO -2007	Oat	Pearl Millet	Sorghum	Finger Millet
Histidine	1.8	0.037	0.108	0.108	0.211
Isolucine	3.1	0.108	0.217	0.022	0.023
Leucine	6.3	0.028	0.172	0.173	0.021
Lysine	5.2	0.035	0.032	2.846	0.021
Methionine + Cystine	2.6	0.027	0.088	0.089	5.923
Phenylalanine + Tyrosine	4.6	0.013	0.077	0.082	0.007
Threonine	2.7	0.111	0.251	0.252	0.022
Valine	4.2	0.052	0.153	0.154	0.018
Amino Acid Score (for adults)					
Isoleucine	3.0	0.112	0.225	0.023	0.024
Leucine	5.9	0.030	0.183	0.185	0.022
Lysine	4.5	0.040	0.037	0.003	0.024
Methionine	1.6	0.045	0.143	0.145	0.010
Cystine	0.6	0.097	0.591	0.628	0.057
Methionine + Cystine	2.2	0.137	0.308	0.310	0.026
Phenylalanine + Tyrosine	3.8	0.057	0.172	0.170	0.021
Threonine	2.3	0.131	0.295	0.296	0.025
Valine	3.9	0.056	0.165	0.165	0.020
Histamine	1.5	0.045	0.130	0.131	0.250

Table 5: Amino acid score for infants/preschool and adults FAO/WHO [25].

Conclusion

The total acidic amino acid was higher in oats, pearl millet and sorghum, while as finger millet was observed to have higher content of basic amino acids. Pearl millet and sorghum was found to have higher content of conditionally essential amino acids arginine, cysteine and proline, and tyrosine. Thus these millets might be useful for supplementation of infant foods and patients with suffering from severe catabolic problems. With respect to the concentration of aromatic amino acids, oats were found to contain the highest percentage and the lowest content was shown by finger millet. Protein efficiency ratios calculated on the basis of interaction between Leucine-proline, and Leucine-tyrosine was found highest in sorghum and finger millet was found to depict the lowest value for both these ratios.

Ethical Statements

Conflict of Interest: The corresponding author and all of the authors declare that they have no conflict of interest and approved in submitting this manuscript.

Data Availability Statement

The data that support the findings of this study will be made available upon reasonable request.

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