



# Evaluation of Physico-Chemical, Nutritional, Mineral, Functional and Phytochemical Analysis in Functional and Nutraceutical Marked Cereals

Shilpa<sup>1</sup>, Sangita Sood<sup>1</sup> and Farhan Mohiuddin Bhat<sup>1\*</sup>

<sup>1</sup>CSK Himachal Pradesh Agricultural Univeristy, Palampur, Himachal Pradesh, India.

## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

The present research was done to analyse the physico-chemical, Nutritional, Mineral, functional and phytochemical analysis in Functional cereals; oats, pearl millet, sorghum and finger millet. The protein content of the analyzed cereals varied from 7.45% to 14.69% with oats having higher concentration of protein content. The higher fibre content in oats accounted for its highest WAC while as the lowest fibre content in sorghum (2.35%) masked its WAC despite containing the highest carbohydrate content. Neutral detergent fiber that gives the measurement insoluble fibre was found highest in sorghum (11.29%) and lowest in pearl millet (5.56%). Total sugars comprising of reducing and non reducing sugars were found highest in pearl millet (2.88%) followed by sorghum (2.14%) and the least content was found in finger millet (1.69%). Oats were found to possess highest content of phosphorus (381.02mg/100g) and finger millet the lowest (8.21mg/100g). Resistant starch that is inaccessible to enzymes was found highest in oats (2.69g/100g) and lowest in sorghum (1.74g/100g).

Keywords: Phytochemical analysis; cereal grains; pearl millet; harvesting.

## 1. INTRODUCTION

Cereal grains are staple foods sources of the world population and are important sources of nutrients and energy worldwide than any other crops [1]. Cereals are usually consumed as a whole or as an ingredient in food stuffs. All the selected cereals in this research work viz. Oats, Finger millet, Pearl millet and Sorghum belongs to the family Poaceae. This family is economically the most important among other plant families due to its potential in providing staple foods from cultivated crops and feed for dairy and meat producing animals [2]. The oat (*Avena sativa*), locally called *Jaei*, is belongs to species of *A. sativa* grown for its seed, Oats are most suitable for human consumption, as well as livestock feed. Oats contain a large amount of protein and well balanced composition of amino acids that makes it highly nutritive as compared to other cereals [3]. Pearl millet (*Pennisetum glaucum*) belongs to the species *P. glaucum*, is the most widely grown type of millet. It has a special quality to withstand harsh weather conditions like drought and flood make it a major source of food to residents of the arid and sub arid regions. Pearl millet is a rich source of proteins, minerals, phytochemicals, vitamins and dietary fibres making it nutritionally comparable and even superior to that of the major cereals [4]. Finger millet also known as *ragi* is a gluten-free grain having low-glycemic index that mark it as a nutraceutical [5]. Finger millet is a rich source of calcium, phosphorus, magnesium and iron besides vitamin B complex such as thiamine, riboflavin, folic acid and niacin [4]. Finger millet also contains minimum fat percentage that makes it beneficial for patients suffering from diabetes mellitus and gastrointestinal tract disorders [6]. Sorghum, (*Sorghum bicolor*), also called great millet, Indian millet belongs to species *S. bicolor* is popular for its edible starchy seeds. It is gluten free crop suitable for consumption by patients suffering from celiac diseases. Sorghum is a rich source of B-complex vitamins and even some varieties contains  $\beta$ -carotene. sorghum is a rich source of contains phenolic compounds like phenolic acids, flavonoids and tannins that are having antioxidant properties and have been found to inhibit tumour development [7]. Sorghum is beneficial for diabetic patients than other cereals as its starches and sugars are released more slowly in human body and thus are having lower glycemic index [8]. The present study was done to determine the physico-chemical, nutritional, functional, photochemical

and mineral analysis of selected functional categorised nutritious cereal grains.

## 2. MATERIALS AND METHODS

### 2.1 Procurement of Raw Material

The raw material was procured and purchased from the breeding stations of CSK Himachal Pradesh Agricultural university (Palampur) of district Kangra, Himachal Pradesh. The chemicals and reagents needed for analysis of proximate composition were purchased from Sigma-Aldrich.

### 2.2 Preparation of Samples

The procured samples were cleaned manually for removing adhering dirt, dust and foreign particles. The grains were ground into fine flour to a specific particle size i.e. with fifty two BSS 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.

### 2.3 Chemical Composition

The moisture, protein, fat and ash contents of the selected cereals were determined by following the standard procedures of AACC (2000). Dietary fiber constituents were determined by following the protocol of Soest and Wine, (1967). Amylose content of the rice starch was determined by following the method of Morrison & Laignelet. (1983). Minerals were estimated by using Atomic Absorption Spectrophotometer, Model 3100, Perkin Elmer. Calcium and Sodium was determined with the help of Flame photometer, Mediflame, 127.

### 2.4 Phyto- Chemical Evaluation

#### 2.4.1 Saponin (Obadoni and Ochuko 2001)

Twenty gram of ground samples were dispersed in 200 ml of 20 per cent ethanol. The suspension was heated over a hot water bath (55°C) for 4 hours with continuous stirring. The mixture was filtered and the residue re-extracted with another 200 ml of 20 per cent ethanol. The combined extract was reduced to 40 ml over a water bath at about 90°C. The concentrate was transferred in to a 250 ml separator funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated and 60 ml of *n*-butanol was added. The combined *n*-butanol extracts were washed

twice with 10 ml of 5 per cent aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to a constant weight. The saponin content was calculated in per cent.

#### 2.4.2 Tannin

Using the method of Makkar et al. (1993) for determination of non-tannin phenolics, 100 mg sample was weighed in test tubes before being added with 1.0 mL distilled water and 1.0 mL of the extracted sample. The tubes were vortexed before kept at 4°C for 15 min. Then, the tubes were vortexed again before centrifuged at 3000 rpm for 10 min. The supernatant was collected and measured for absorbance at 725 nm using spectrophotometer (Shimadzu, Australia). The tannin content was calculated as follows:

$$Tannin = TotalPhenolic - nontannin$$

Total phenolic and tannin content were expressed as gallic acid equivalents through the calibration curve of gallic acid with the concentration range of 0-100 mg/ml.

#### 2.5 Determination of Total starch

Total starch (TS) was determined by the AOCC Method 76.13 using the Total Starch Assay Procedure Kit (Megazyme Int, Ireland). A 100 mg of dried ground sample was dispersed with 0.2 mL of aqueous ethanol (80%v/v). Immediately 3 ml of thermostable  $\alpha$ -amylase in a MOPS buffer was added and the tube was incubated in a boiling water bath for 6 min with continuous stirring alternately after 2 to 4 minutes. The tube was placed in a water bath at 50°C, and 4 mL of sodium acetate buffer (200 mM, pH 4.5) was added followed by amyloglucosidase (0.1 mL, 20 U). The tube was stirred on a vortex mixer and incubated at 50°C for 30 min. Then, the volume was adjusted to 100 mL with distilled water. An aliquot of this solution was centrifuged at 3,000 rpm for 10 min. Duplicate aliquots (0.1 mL) were transferred to test tubes and 3 mL of the glucose oxidase reagent was added. The incubation with the reagent was done at 50°C for 20 min, and the absorbance was measured at a wavelength of 510 nm against the reagent blank. Glucose concentration was converted into starch by multiplying by 0.9.

#### 2.6 Determination of Resistant Starch

Resistant starch (RS) was determined enzymatically by the method of Goni et al.

(1996). 100 mg of ground sample was incubated with a solution of 20 mg of pepsin from porcine gastric mucosa (P-7000) in a KCl- HCl buffer for 60 min at 40°C. After cooling the sample at room temperature, 9 mL of 0.1 M Tris-maleate buffer (pH 6.9) was added followed by 1 ml of a solution of 40 mg of  $\alpha$ -amylase from porcine pancreas (A-3176.). The sample was incubated at 37°C for 16 h with constant shaking. The hydrolyzate was centrifuged and the supernatant discarded. The residue was moistened and 3 mL of KOH was added to solubilize the residual starch, shaking for 30 min at room temperature. After adjusting the pH to 4.75 (using 0.4 M sodium acetate buffer and 2 M HCl), 80  $\mu$ l of amyloglucosidase from *Aspergillus niger* (A-1602, Sigma-Aldrich Inc.) was added, mixed well and left for 45 min in a water bath at 60°C with constant shaking. The solution was centrifuged and the supernatant collected in a 25 mL volumetric flask. After adjusting the volume with distilled water, duplicate aliquots (0.1 mL) of this solution were transferred into test tubes and the reagent from the glucose determination kit (Megazyme Int, Ireland) was added and the absorbance was read as described in the total starch analysis. The resistant starch was calculated as mg of glucose x 0.9.

#### 2.7 Physical Evaluation

##### 2.7.1 Colour and shape

The colour and shape of the selected seeds of the test samples were observed from their physical and visual appearance.

##### 2.7.2 Thousand kernel (seed) weight

Thousand kernels (seed) weight was determined by weight of randomly selected 100 kernels by means of electronic balance (accuracy of 0.001 g) and multiplying their weight by 10.

##### 2.7.3 True density

The true density was measured by toluene displacement method.

One thousand grains of test crops were weighed and put in graduated cylinder containing known amount of toluene. Rise in toluene level was noted and true density was reported by using the formulae

$$Truedesnsity (g/ml) = \frac{W (g)}{V (ml)}$$

Where 'W' is weight of one thousand grains and 'V' is rise in toluene level after the addition of the grains.

#### 2.7.4 Bulk density

The grains of test crops were filled in measuring cylinders up to certain level from the constant height followed by weighing. The bulk density was determined by using the formula

$$\text{Bulkdensity (g/ml)} = \frac{\text{Weight (g)}}{\text{Volume (ml)}}$$

#### 2.7.5 Porosity

Porosity was analyzed by using the relationship of bulk density and true density as follows.

$$\text{Porosity} = 1 - \frac{(\text{truedensity} - \text{bulkdensity})}{\text{Bulkdensity}} \times 100$$

### 2.8 Functional Properties Evaluation

#### 2.8.1 Water absorption index (WAI) and water solubility index (WSI) (Anderson, 1982)

Accurately weighed 2.0 g sample was taken in centrifuge tube, which was previously dried and weighed followed by 20 ml of distilled water and kept in water bath for 10 minutes at 85°C. Sample was cooled and centrifuged at 3500 rpm for 15 minutes. Supernatant was decanted in pre weighed petri plate and sediment was weighed.

For water solubility index after centrifuging at 3500 rpm for 15 minutes, the supernatant decanted in pre weighed petri plate. Then dried for 1-2 hours at 100°C and weighed. The WAI and WSI were calculated by the following formulas.

$$\text{WAI} = \frac{\text{Weight of sediment (g)}}{\text{Weight of solids (g)}}$$

$$\text{WSI} = \frac{\text{Weight of dissolved solids in supernatant (dried)}}{\text{Weight of dry solids}} \times 100$$

#### 2.8.2 Water and oil absorption capacity (Sosulski et al., 1976)

The sample (1.0 g) was mixed with 10 ml water or refined soybean oil, kept at ambient temperature for 30 minutes and centrifuged for 10 minutes at 2000 rpm. Water or oil absorption capacity was expressed as per cent oil bound per gram of the sample.

### 2.9 Foaming Capacity and Foaming Stability

The Foaming capacity (FC) and the Foam stability (FS) of the flour samples were determined by slightly modifying the procedure suggested by Kaur and Singh (2005). The dispersion of flour samples in 50 ml of distilled water at the rate of 3% w/v was homogenized vigorously for 3-5 minutes using a high-speed scattering machine at 10,000 rpm. The blend is immediately transferred to a graduated cylinder and the homogenizer cup was rinsed with 10 mL distilled water, which was then added to the graduated cylinder. The volume was recorded before and after whipping and measured as the percent of volume increase due to whipping. The foaming capacity was expressed as the percentage of volume increase. For the determination of foaming stability, a change in the foam volume in the graduated cylinder was recorded after 1 hour of storage. The FC and FS were calculated by the following formulas.

$$\text{FC(\%)} = \frac{V2 - V1}{V2} \times 100$$

$$\text{FS(\%)} = \frac{V3}{V2 - V1} \times 100$$

## 3. RESULTS AND DISCUSSION

### 3.1 Chemical Composition of Selected Cereals

The crops under study were evaluated for different proximate constituent's viz. moisture, ash, crude fat, crude fiber, protein and carbohydrates as represented 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 satbility, eating quality, nutritive value and processing requirements. Moisture content has an essential role in determining the physical appearance and kernel morphology of cereal grains [9]. All of the analyzed cereals 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 [10]. Ash content gives an index to the mineral matter in food materials and was observed to vary from 1.43 to 3.50 per cent. The presence of

higher ash content in oats reflects the availability of more minerals among the selected cereal grains as reported earlier by Klava. [11]. The decreased ash content in sorghum and millets could be attributed to processing of these cereals that lowers down 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 flavour and excessive browning of toasted products [12]. 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. [13] who reported  $5.49 \pm 0.76$  per cent fat content in oat. The protein content of the analyzed cereals 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 [14]. 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 2.70 to 5.34% with sorghum having the least fiber content and oats having the highest fiber content. The polysaccharide  $\beta$ -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 [14]. 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 per cent. Starch is the main carbohydrate present in finger millet and amylopectin constitutes about 80 to 85 per cent of the finger millet starch [15].

### 3.2 Physical Parameters of Selected Cereal Crops

The physical properties of selected cereals viz. Oats, Finger millet, Pearl millet, Sorghum are presented in Table 2. The oats grains were found to be creamish in colour having the shape of

elongated spindle. While as pearl millet and sorghum were found to be oval shaped with shades of gray and red. The red colour in sorghum could be attributed to the presence of anthocyanidin pigments present in its pericarp [16]. Colour is also an important quality attribute that has a marked impact on consumer acceptability for product and is an indicator of nutritional and functional value of the selected cereal crop. Thousand kernel weight of the analysed cereals were found to vary from 2.31g to 31.73 g with sorghum showing the highest value and finger millet the lowest. The lesser thousand kernel weight indicates the presence of damaged, immature and shrivelled grains, which in turn results in poor milling yield. The highest thousand kernel weight and bulk density in sorghum could be attributed to the presence of starch granules located within the endosperm and in pericarp unlike other cereal grains as validated earlier by Serna-Saldivar and Rooney [17]. The finger millet grain having an average a tenth size of sorghum consists limited starch content of 55.1% having molecular weight lower than that of other cereal starches that accounted for its lowest thousand kernel weight among the given cereals as reported earlier by Serna-Saldivar et al. [17] and Singh and Ali. [18]. The mean value for density and bulk density was found to be 1.45 & 0.72, 1.25 & 0.87, and 1.36 & 0.72g/ml for Pearl millet, Sorghum and Finger millet respectively. Vannalli et al. [19] reported thousand kernel weights of ten different varieties of Sorghum between the ranges of 25.59 to 41.01g which are in line with the given values. Nazni and Bhuvaneshwari [20] reported the values of thousand kernel weight  $2.46 \pm 0.005$ g, which is on the higher side where as the value of bulk density reported as  $0.70 \pm 0.01$ g/ml which is pretty closer to the present result. The slight variations might be due to the agro-climatic variations coupled with harvesting maturity. The low bulk density in oats could be attributed to elongated spindle shape that occupies space by maintain distance between the grains resulting in reduction of total mass per unit volume [21]. The porosity value attained as 43.27, 20.12, 30.20 and 46.94 g/100 g for Oat, Pearl millet, Sorghum and Finger millet respectively. The bulk density of legume flour plays an important role in weanling food formulation, that is, reducing the bulk density of the flour is probably helpful to the formulation of weanling foods [22]. Porosity and density are the basic attributes used to solve the problems of agricultural products during drying and storage periods and to maintain the quality characteristics until consumption.

**Table 1. Chemical parameters of selected Millets (per cent)**

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

**Table 2. Physical parameters of selected Cereal Crops**

Parameters Crops	Colour	Shape	1000 Kernel Wt. (g)	Density (g/ml)	Bulk Density (g/ml)	Porosity (g/100g)
Oat	Cream	Elongate spindle	26.95	1.01	0.58	43.27
Pearl Millet	Gray	Oval	9.05	1.45	0.72	20.12
Sorghum	Red	Oval	31.73	1.25	0.87	30.20
Finger millet	Redish	Round	2.31	1.36	0.72	46.94
	Brown					

### 3.3 Functional Properties Evaluation

#### 3.3.1 Functional parameters of selected cereal crops

Functional properties play an essential role in analysing their potential for various food applications and are presented in Table 3. The WAC that determines the ability of the cereals to bind with water were found to be highest in oats (189.00%), while as sorghum were found to depict the least WAC of 61.03%. The oats with highest water absorption might be due to excess amount of hydrophilic constituents, such as polysaccharides as reported previously by Hodge and Osman [23]. The variations in protein structure and hydrophilic carbohydrates accounted for variations in the WAC of analysed cereals. The higher fibre content in oats accounted for its highest WAC while as the lowest fibre content in sorghum (2.35) masked its WAC despite containing the highest carbohydrate content. WAC plays an important role in determining the role of flour in various food products like dough, soups and baked products [24]. The OAC the determines the ability of cereals to retain flavour and enhance mouth feel were found to be highest in oats (205.00%), while as sorghum was found to possess least OAC of 76.23%. The mechanism of oil absorption involves capillary interaction enabling the retention of the absorbed oil. Higher WAC leads to development of a softer product whereas higher OAC results in increasing crispness by acting as shortening for the products like pastries, cake and biscuits etc. The

variations in functional properties of different cereal may be ascribed to the relative ratio of different constituents like proteins, carbohydrates and lipids. The differences in oil binding capacities of different varieties could be attributed to variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil and thus enhance the capacity of cereals to bind oils [25]. The ability of different cereals to absorb and retain water and oil may help improve binding of the structure, enhance flavour retention, improve mouthfeel and reduce moisture and fat losses of during processing operations [26]. The foaming properties consisting of foaming capacity and foam stability are desirable characteristics for the production of frozen desserts and whipped deserts. Foams are indicators of the ability of flour in determining the desired texture, consistency and appearance of diverse range of food products [27]. The excess foaming capacity in finger millet (63.0%) could be attributed to higher protein to fat ratio that reduces the interfacial surface tension between air and water leading to stability of air bubbles by providing a cohesive film of protein around it [28]. The good foaming ability of finger millet could account for its application in food systems that require aeration for textural and leavening properties. The reduction in stability of foams could be attributed to the drainage of liquid from the lamellae accompanied by an increase and then rupture in the size of air bubbles responsible for foam formation [29]. The lower foaming capacity and stability of 18 and 12 % in oats could be attributed to its higher fibre content that breaks

the stability of air bubbles in the foam as validated earlier by Tagodoe and Nip. [30].

The water absorption index (WAI) gives the measurement of volume occupied by the starch after swelling in excess water was found to be highest in pearl millet showing value of 8.25%. Water solubility index indicates the amount of polysaccharides released from the starch granule on addition of excess of water was found to be highest in pearl millet (9.13%) and lowest in oat (2.25%). The increase in WAI of pearl millet may be due to solubility of carbohydrates and increased level of damaged starch as reported earlier Singh et al., [31].

### 3.4 Nutrition Evaluation

The analysis of nutritional parameters in the experimental cereal grain (Table 4) showed that Acid Detergent Fiber (ADF) was highest in sorghum (5.53%) and finger millet (5.86%), indicating that these contain highly indigestible part of forage including cellulose and lignin but not hemicelluloses. Neutral detergent fiber (NDF) that gives the measurement insoluble fibre consists of most of the structural components in plant cells like lignin, hemicelluloses and cellulose excluding pectin was found highest in sorghum (11.29%) and lowest in pearl millet (5.56%). Difference between NDF and ADF gives measurement of hemicellulose content was found highest in sorghum (5.76%) and lowest in pearl millet (2.44%). Lignin that is responsible for cementing together cellulose microfibrils providing increased compression strength was found highest in sorghum (1.10%) indicating defence against pathogenic invasions. Cellulose is a type of insoluble fiber having no calories passing through digestive tract unchanged was found highest in finger millet (5.56%) and sorghum (4.43%), thereby imparting health benefits upon consumption of these cereals. Devi et al. [32] analyzed the twelve cereal grains and reported the total dietary fiber

of Sorghum, Finger millet and Pearl millet as 11.8, 19.1, and 7.0 respectively. The values of the dietary fiber are on the lower side which might be due to the varietal variation and maturity at harvesting stage.

#### 3.4.1 Nutrition composition of selected cereal crops

Total sugars comprising of reducing and non-reducing sugars were found highest in pearl millet (2.88%) followed by sorghum (2.14%) and the least content was found in finger millet (1.69%). Glucose, fructose and sucrose have been found as prominent sugars in millets. The lowest levels of reducing sugars in the analysed grains contributed their functional usage in management of type II diabetes due to their hypoglycaemic activities. Circulating reducing sugars such as glucose react non-enzymatically with proteins (the Maillard reaction) to initiate a posttranscriptional modification process known as advanced glycation. The carbohydrate decreased during the germination due to increase the soluble sugar (carbohydrate) and these changes could be attributed to the activities of the alpha amylase activity which breaks down complex carbohydrates into simpler and more absorbable sugars. Nutan (2015) also reported the total soluble sugars, reducing sugars, non-reducing sugars as  $1.68 \pm 0.09$ ,  $0.50 \pm 0.02$ ,  $1.18 \pm 0.01$  per cent respectively in oat. Nirmala et al. (2000) reported value of 1.5 per cent reducing sugar and 0.03 per cent non-reducing sugar in Finger millet. The oral micro biome possesses the capacity to metabolize sugars; however, sugars are not metabolized similarly by all oral microbes. *Streptococcus mutans* is considered the key microorganism in the oral cavity that has been linked to dental caries [33]. The higher percentage of non-reducing sugars in pearl millet (2.11%) and oat (1.19%) among the analysed crops determines their potential in minimizing browning in their baked or fried products.

**Table 3. Functional parameters of selected cereal crops**

Crops	Oat	Pearl Millet	Sorghum	Finger Millet
WAC %	189.00	72.01	61.03	64.21
OAC%	205.00	84.21	76.23	78.23
FC%	18.00	27.00	36.00	63.00
FS%	12.00	18.00	25.00	51.00
WSI (g/g)	2.25	9.13	2.83	6.12
WAI (%)	4.50	8.25	0.74	1.23

**Table 4. Nutritional parameters of selected cereal crops (per cent)**

Crop	Oat	Pearl Millet	Sorghum	Finger millet
<b>Parameters</b>				
ADF	2.02	3.12	5.53	5.86
NDF	6.86	5.56	11.29	9.02
Lignin	0.39	0.23	1.10	0.30
Hemi Cellulose	4.91	2.44	5.76	3.19
Cellulose	1.39	2.89	4.43	5.56
T.D.Fiber	9.27	8.91	17.92	15.21
T.Sugar	1.71	2.88	2.14	1.69
R.Sugars	0.51	0.77	0.80	0.06
N.R Sugars	1.19	2.11	1.34	1.63

### 3.5 Mineral Evaluation

#### 3.5.1 Mineral composition of selected cereal crops (mg/100g)

The mineral composition in the experimental cereals had been presented in Table 5. Among the analysed cereals finger millet was found to possess highest content of calcium (269.54mg/100g) followed by oats (78.05%). A cereal rich in calcium assist in bone development in children and plays a role in most metabolic processes. Magnesium that plays an important role in assisting the enzymatic reactions in human body and regulates the muscle contraction and heart beat was found to be highest in finger millet (343.00 mg/100g) and lowest in sorghum (112.09mg/100g). Potassium that is an essential nutrient required for maintenance of total body fluid volume balance, acid and electrolyte balance and normal cell function as reported by Yung [34] was found highest in oats (379.46 mg/100g), while as finger millet was observed to have the least concentration of 5.10%. Oats were found to possess highest content of phosphorus (381.02mg/100g) and finger millet the lowest (8.21mg/100g). Phosphorus is the main structural component of bones, teeth and cell membranes and is an essential element in production of energy. Iron is an essential element involved in the formation of haemoglobin, and transport of oxygen and electron in human body was found highest in pearl millet (12.08mg/100g) and lowest in sorghum (3.84mg/100g). The zinc content varied from 1.32mg/100 in sorghum to 3.03mg/100g in oats and pearl millet. Zinc plays an important role in growth, metabolism, development and an essential co-factor for large number of enzymes in the body. An analysis of the given samples indicated that all of these have ratio of sodium to potassium less than one that validated that these could be recommended for

persons suffering from high blood pressure and in formulation of diets for children with immature heart [35].

#### 3.5.2 Starch and glycemic index evaluation of selected cereal crops (g/100g)

Starch that provides the main carbohydrate content was found highest in oats (9.43%) and finger millet (7.53%), while as pearl millet and sorghum contained lowest content of 5.73 g/100g and 5.09g/100g respectively as shown in Table 6. Starch granules are present in compacted form in the cellular matrix of endosperm in millets are of vitreous nature as reported earlier by Ushakumari et al. [36]. The glycemic index values of the given cereals were found to be in line with the starch content as validated from the table in which higher starch containing cereal was found to possess highest glycemic index value and vice versa. The low glycemic index cereals could be an essential diet for those suffering from chronic diseases related to obesity such as diabetes and cardiovascular disease. Resistant starch that is inaccessible to enzymes was found highest in oats (2.69g/100g) and lowest in sorghum (1.74g/100g). Resistant starch imparts beneficial effects by providing fermentable carbohydrates for colonic bacteria and thus reducing several intestinal disorders including colon cancer [37]. Amylose that is a tightly packed helical structure and is more resistant to digestion than other starch molecules was found to depict the same trend as resistant starch with oats having the maximum value and sorghum the lowest.

### 3.6 Phyto-Chemical Evaluation

Tannins that are having beneficial effects due to its antioxidant properties were found higher in pearl millet (228.00mg/100g) and lowest in oat (0.12mg/100g) as represented in Table 7. Tannins are oligomers and polymers of flavan-3-



**Table 5. Mineral composition of selected cereal crops (mg/100g)**

Crops	Oat	Pearl Millet	Sorghum	Finger Millet
Ca	78.05	27.82	22.56	269.54
Mg	135.25	124.23	112.09	343.00
P	381.02	218.09	208.35	8.21
K	379.46	39.01	302.06	5.10
Fe	4.42	12.08	3.84	5.0
Zn	3.03	3.03	1.32	2.81
Na	7.95	7.08	7.17	0.95

**Table 6. Starch and Glycemic index evaluation of selected cereal crops (g/100g)**

Crops	Oat	Pearl Millet	Sorghum	Finger Millet
STARCH	9.43	5.73	5.09	7.53
R.STARCH	2.69	2.50	1.74	2.38
Amylose	18.20	15.56	12.37	12.62
GI	40.78	40.34	40.18	40.53

**Table 7. Phyto-chemical constituents of selected cereal crops (mg/100g)**

Crops	Oat	Pearl Millet	Sorghum	Finger Millet
Saponin (mg/100g)	2.30	0.20	0.89	5.29
Tannin (mg/100g)	0.12	228.00	1.55	1.73

ols impart beneficial effects like immunomodulatory and anticarcinogenic activity, radical scavenging functions; anti-inflammatory, cardio protective, vasodilating, and antithrombotic effects [38]. Saponins known to produce inhibitory effect on inflammation and having the property of precipitating and coagulating red blood cells was found maximum in finger millet (5.29mg/100g) and lowest in pearl millet (0.29mg/100g). The higher concentration of saponin in finger millet and oats could be beneficial in its protection against attack by pathogenic microbes. The presence of these anti-nutritional factors decreases the bioavailability of micronutrients due to chelating of minerals in the gastrointestinal tract [39]. The concentration of these anti-nutritional factors can be reduced to limited levels by several treatments like soaking, roasting, boiling, milling, parboiling, germination and extrusion cooking [40].

#### 4. CONCLUSION

All of the analyzed cereals 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. The highest thousand kernel weight and bulk density in sorghum could be attributed to the presence of starch granules located within the endosperm

and in pericarp. The WAC that determines the ability of the cereals to bind with water were found to be highest in oats (189.00%), while as sorghum were found to depict the least WAC of 61.03%. Cellulose having no calories passing through digestive tract unchanged was found highest in finger millet (5.56%) and sorghum (4.43%). Among the analysed cereals finger millet was found to possess highest content of calcium (269.54mg/100g) followed by oats (78.05%). Tannins that are having beneficial effects due to its antioxidant properties were found higher in pearl millet (228.00mg/100g) and lowest in oat (0.12mg/100g).

#### DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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