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4. Nutritional Composition and Functional Properties of Millets

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Abstract:

In the 21st century, changes in climate, water shortages, a growing world population, increasing food prices, and other social and economic impacts are expected to pose a major threat to agriculture and food security globally, especially for the poorest people living in arid and semi-arid areas. These challenges call on scientists and nutritionists to explore the possibilities of producing, processing, and using other potential food sources to end hunger and poverty. Cereal grains are the most significant source of food worldwide and play a key role in human diets globally. As one of the most important drought-resistant crops, millet is widely cultivated in the semi-arid tropics of Africa and Asia and is a major source of carbohydrates and proteins for people in these regions.

Moreover, due to their important contribution to national food security and potential health benefits, millet grains are now receiving growing interest from food scientists, technologists, and nutritionists.

The objective of this work was to review recent advances in research conducted to date for evaluating the nutritional quality and potential health benefits of millet grains.

Processing technologies used for improving the edible and nutritional qualities of millet as well as challenges, limitations, and future perspectives to promote millet utilization as food for a large and increasing population are also discussed. Millets are a major source of food for humans, and their production has been increasing steadily in recent decades to meet the dietary needs of the growing global population. Millets are an outstanding source of all the essential nutrients such as protein, carbohydrates, fat, minerals, vitamins, and bioactive compounds.

Keywords:

Drought-Resistant Crops, National Food Security, Essential Nutrients, Bioactive Compounds.

4.1 Millets:

The millets grown in India are a nutritious, drought-resistant group of small-seeded grasses that belong to the *Poaceae* family **(Holes, Laing and Pearson, 1980)**.

These millets are a crucial source of food and animal feed for millions of financially disadvantaged farmers across arid and semi-arid parts of India. They play a key role in maintaining ecological balance and economic stability in the country.

According to the **ICMR-National Institute of Nutrition** millets are also referred to as **"coarse cereals"** or **"poor man's cereals"**. Compared to wheat and rice, Indian millets have higher amounts of protein, vitamins and minerals. They are gluten-free with low glycemic index which makes them suitable for people with celiac disease or diabetes.

4.2 Benefits of Millets:

Millets are highly flexible to a wide range ofenvironmental conditions and grow well in rain-fed, arid climates. They require minimalwater, fertilizers, and pesticides. Millets have superior nutrient profiles and bioactive compounds compared to other grains.

They are low on the glycemic index and associated with diabetes prevention. Millets are good sources of iron, zinc and calcium. They are gluten-free and can beeaten by those with celiac disease. **(Ambati and Sucharitha 2019).**

Millets can help manage and prevent high cholesterol and cardiovascular disease risk. They aid in weight and BMI reduction and lowering high blood pressure. In India, millets are often eaten with legumes, which enhances overall protein quality and digestibility.

Ready-to-eat and ready-to-cook millet products are conveniently accessible for urban populations. Millets serve dual purposes as food and animal feed, improving farming efficiency. Millet cultivation helps reduce carbon footprint.

4.3 Types of Millets:

There are the differenttypes of millets are distributed their grain sizeof the millets, these are classified into three types:

A. Major Millet:

The major millets are a category depending on their size of grains with high energy and nutrient content. Major millets are considered major because they are cultivated and consumed as staple crops in many parts of the world, these are further classified into three types. **Sorghum (**Jawar), **Pearl millet** (bajra), **Finger millet** (Ragi).

B. Minor Millet:

The minor millet is acategory of small grains with high energy and nutrients content. They are also referred to as micro millets or small millets.

These are also classified into Five types: **Little millet** (kutki), **Foxtail millet** (Kangani), **Barnyard millet** (sanwa), **Kodo millet** (kodo), **Proso millet** (Chena).

C. Pseudo Millet:

Pseudo millets are called so because they do not belong to the *Poaceae*botanical family, which includes 'true' grains.However, they have similar nutritional profiles and culinary uses as 'true' grains.Although not technically millets, pseudo millets are highly nutritious, non-glutinous, and alkaline foods. This paraphrased versionretains the original meaning and structure of the text while using different vocabulary andphrasing. These are basically two types: **Amaranth** (Ramdana), **Buckwheat** (Kuttu).

4.3.1 Major Millet:

A. Sorghum Millet:

Sorghum, also referred to as jowar, is a cereal grain cultivated in India. Sorghum is a crop from the Gramineae family that contains high amounts of carbohydrates and has the scientific name Sorghum bicolor L. It is a drought-resistant crop that can be grown in areas with minimal or no irrigation. Sorghum is a nutritious grain abundant in fiber and protein. It is also a good source of vitamins andminerals, such as iron and magnesium.

Sorghum is typicallyutilized to make flour, which is used to prepare bread, porridge, and other food items. It is one of the staplecrops for millions of semi-arid inhabitants and is also known as the **"KING OF MILLETS"**.

Table 4.1: Nutritional composition of Sorghum Millet (nutrient per 100g)

Protein (g)	10
Fiber (g)	4
Minerals (g)	1.6
Iron (mg)	2.6
Calcium (mg)	54

Functional properties of Sorghum millet:

The fundamental physico- chemical properties that reflect thecomplex interactions between thecomposition, structure, and molecularconfiguration of food components along with the environment they are measured in are known as functional properties.

Functional characteristics are needed to evaluate and potentiallypredict how novel proteins, fats,fibers and carbohydrates may act in specific systems and demonstratewhether such proteins can stimulate or replace conventional proteins. Thefood property describes the structure,quality, nutritional value and acceptability of a food product.

A functional property of food is determined by the physical, chemical and/or sensory properties of that food.Examples of functional properties include solubility, absorption, water retention, foaming ability, elasticity and absorption capacity for fat and foreign particles.

Typical functional properties consist of pasting properties, emulsification, hydration (water binding), viscosity, foaming, solubility, gelation, cohesion and adhesion.

Water Absorption Capacity(WAC):

The water absorption capacity refers to the amount of waterthat flour can take in to achieve the desired consistency and produce a high-quality final product.

Flour with high water absorption may contain more hydrophilic components like polysaccharides. Proteins have both hydrophilic and hydrophobic properties, so they can interact with water in foods. An increase in water absorption capacity has always been linked to more amylose leaching and solubility, as well as a loss of starch crystalline structure.

A study on the water absorption capacity of sorghumflour found it ranged from 74.08 to 76.83 ml/100 g, compared to wheat and soybean flour respectively. The differences seen in various flours maybe due to varying protein concentrations, the extent of their interaction with water, and theirconformational characteristics.

Oil Absorption Capacity (OAC):

The ability of sorghum flour to absorboil (OAC) has been linked to thephysical trapping of oil within theflour. This is significant because oilacts to retain flavor and enhance the taste of food for consumers.

Numerous studies have examined theoil absorption capacity of sorghumflour under varying conditions,yielding different results. An increasein the OAC of sorghum was observedover a 3-day germination period inone study. The biggest increase inOAC occurred on the third day ofgermination (121.17%).

Theenhanced OAC could be due tochanges in protein quality duringgermination, as well as the flour'scapacity to hold oil globules as lipophilic proteins increase.

Since lipid binding depends on the availability of hydrophobic amino acids on the surface, the improved oilabsorption of germinated samples may stem from more exposed non- polar residues in protein molecules. Ahigher oil-binding capacity suggests the flour could be useful for foods thatneed to retain oil.

Bulk Density:

Bulk density measuresthe heaviness of flour and is typicallyinfluenced by the particle size anddensity of the flour. It is crucial in determining the packaging needs,material handling, and application in wet processing in the food industry. The bulk density of sorghum after germinating for three days ranged from 0.83 g/cm3 to 0.70 g/cm3.

A minor decrease in bulk density with longer germination time aligns with previous research. This reductioncould be due to decreases in the heaviness and dispersibility of the flour samples.

Bulk density indicatesthe relative volume of packaging material needed. Higher bulk densityis preferable for greater ease ofdispersibility and thinner pastes, which is important for feeding convalescent children.

Foaming Capacity and Stability:

The foaming ability (FA) and foam stability (FS) are determined by measuring the volume decrease caused by destabilization and liquid loss. Foam formation is controlled by three factors: movement, infiltration, and rearrangement of the molecule at the air-water interface.

Thus, for good foaming, the protein should be able to move to the air-water interface, unfold and rearrange at the interface. **Yagoub and Abdalla (2007)** presented results of FA which ranged from 116.55% to 151.58%. An increase in FA may be initiated by a decrease in surface tension at the air and water interface, which in turn causes the absorption of soluble protein molecules for hydrophobic interactions.

The FA of a food material depends on the surface-active properties of its protein. It has been observed that germination could improve the FS of sorghum flour as the FS was enhanced with increasing germination time.

Furthermore, germination may have caused surface denaturation of the proteins and reduced the surface tension of the molecules, which gave an improved FS. Therefore, FS is an important property because the usefulness of whipping agents depends on their ability to maintain the foam as long as possible.

Gelatinization Temperature:

The gelatinization temperature is the point at which starch granules in a food lose their structure and amylose leaks out, affecting the time needed to cook the food. The gelatinization temperatures of the flour samples studied by Iwe et al. ranged from 29.00 to 74.000°C, within the <75°C range reported by ARSO.

There was significant variation in the gelatinization temperatures of the different flour types. According to **Chandra and Samsher (2013),** flour with more starch content gelatinizes at lower temperatures, while flour with less starch requires higher temperatures to gelatinize

Least Gelation Concentration:

The lowest gelation concentration of flour from germinating sorghum varied from 12% to 16%. The ability to form gels improved as the germination time increased. Non-germinating sorghum flour had the poorest gelation capacity, while flour from 3-day germinated sorghum had the highest gelation capacity.

The lowest gelation concentration for germinating sorghum flours was 16%, 14% and 12% on day 0, day 2 and day 3 of germination, respectively. The results showed that the optimal lowest gelation concentration for germinating sorghum flours was 12% (w/v).

The enhancement in gelation capacity with increasing flour concentration was mainly due to a decrease in the thermodynamic affinity of proteins for the solution, which amplified the interactions between different proteins. Note that the lowest gelation concentration for germinating millet flour was 8%.

These variances could be linked to the relative proportions of different protein, carbohydrate and lipid constituents. Also, the variation in the lowest gelation concentration in this study could arise from the aggregation of denatured protein molecules, which increased protein concentration or solubility and prompted intermolecular contacts during heating.

This observation also signified that amylase released during germination would have interacted with the starch component of the flour, improving its gelling properties. Therefore, it is recommended to use sorghum flour from 3-day germinated grains to accomplish good gel-forming or firming agent quality.

Pasting Properties:

The pasting properties of flour are important for predicting its behavior during and after cooking. The differences in peak viscosity seen in the samples indicate varying degrees of starch gelatinization and amylose content in the blends. Sanni et al. noted that high peak viscosity is closely linked to high starch damage, which in turn increases viscosity.

Bhupender et al., researched the pasting properties of sorghum from different cultivars using RVA. Starches from different cultivars showed significant variation in all their pasting parameters. The starch suspensions displayed a gradual viscosity increase with rising temperature.

This viscosity increase with temperature may be due to water removal from the exuded amylose by the swelling granules. Peak viscosity is an indicator of water binding capacity and the ease of starch granule disintegration, and is often correlated with final product quality. The peak viscosity of the different starch samples ranged from 1665 to 1998 cP. The breakdown viscosity of starch from the different sorghum cultivars ranged from 414 to 769 cP.

The breakdown is caused by the disintegration of the gelatinized starch granule structure during continued stirring and heating, indicating the shear-thinning property of starch. A low breakdown value suggests the stability of starches under hot conditions. Amylose content is believed to strongly influence breakdown viscosity (a measure of cooked starch granule susceptibility to disintegration) and setback viscosity (a measure of recrystallization of gelatinized starch during cooling).

Lower amylose levels to reinforce the molecular network within the granules resulted in greater breakdown viscosity. High amylose content has also been suggested as the major factor contributing to the absence of a peak, high stability during heating, and high setback during cooling.

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B. Pearl Millet:

Pearl millet is the most widely grown type of millet. This summer cereal grass is distinguished by its large stems, leaves, and seed heads. Bajra, variety of millet, is one of the most commonly growncrops in India. It is a short-seasoncrop that can be cultivated in both rain-fed and irrigated fields. Bajra is abundant in proteins, minerals, and vitamins and provides good energy. Itis an excellent source of dietary fiberas well.

Table 4.2: Nutritional composition of PearlMillet (nutrient per 100g)

Protein (g)	10.6
Fiber(g)	1.3
Minerals (g)	2.3
Iron(mg)	16.9
Calcium (mg)	38

a. Functional Properties of Pearl Millet:

Pearl millet has different functional properties depending on their nutritive component and the structure of millet grains; it shows different functional properties:

b. Oil and Water Absorption Capacity (OAC) & (WAC):

The ability of an oil to be absorbed is significant because oil helps keep the flavor and improves the texture of foods. Pearl millet has a relatively high oil absorption capacity. This suggests that pearl millet could better retain flavor when used in food recipes. The high-water absorption capacity in the three samples should be highlighted. The degree of protein hydration is strongly related to the amount of polar and charged amino acid residues. Interactions between water molecules and hydrophilic groups happen through hydrogen bonding.

c. Least Gelation Concentration:

The minimum concentration needed to form a gel varied between the different grains, with pearl millet requiring the lowest concentration at 12.0% w/v. This variation may be related to the relative proportions of different components in the grains - proteins, carbohydrates, and lipids. Interactions between these components can influence functional properties.

Pearl millet had the lowest gelation concentration at 12.0% w/v. The ability of proteins to form gels and provide a structural matrix to hold water, flavours, sugars and other food ingredients is useful for food applications and developing new products. T his adds another dimension to protein functionality. The low gelation concentration seen in these grains may be advantageous for using flours or protein concentrates to make curds or additives to improve gelling in other food products.

d. Emulsion Capacity and Stability:

The original text discusses the emulsion capacity and stability of pearl millet flour. It states that pearl millet flour has an emulsion capacity of 89.0%. This value is similar to that reported for pigeon pea flour, but higher than the emulsion capacities of wheat flour (7.00-11.00%) and soybean flour (18.00%). This suggests that pearl millet flour may be useful as an additive for stabilizing fat emulsions in foods like sausage, soup, and cake. After 24 hours, the emulsion stability or water separation volume for pearl millet flour was 34.0%. Over 24 hours, all the flours produced good and stable emulsion stability. The foaming capacity of the flours is also presented. Pearl millet flour had a foaming capacity of 11.3.

C. Finger Millet:

Finger millet is another key cereal grain grown in Eastern Africa and Asia, often called ragi in India. The plant has many spikes or "fingers" at the top of the stem. The grains are very small (1-2 mm across). Finger millet grains contain high levels of minerals, dietary fiber, polyphenols, and proteins. Finger millet, being rich in calcium, is important for growing children, pregnant women, and people with obesity, diabetes, or malnutrition. It has abundant potassium which allows proper functioning of the kidneys and brain, enabling smooth operation of the brain and muscles.

Table 4.3: Nutritional Composition of Finger Millet (nutrient per 100g)

Protein (g)	7.3
Fiber(g)	3.6
Minerals (g)	2.7
Iron (mg)	3.9
Calcium(mg)	344

a. Functional Properties of Finger Millet:

Finger millet, which is also called ragi, possesses numerous. functional characteristics: the ability to absorb water, bulk density,dispersibility, viscosity, and micro-structure.

- **Oil absorption capacity (OAC):**

The oil absorption capacity (OAC) ofthe various millet flours that werestudied showed that finger millet flour had an OAC of 1.93g/g. Flours with high water and oil absorption capacities can have a positive impacton the flavor, moisture and fat contentof food, leading to better organolepticcharacteristics. Color is a crucial quality factor that directly affects the acceptability of food products, making it an important physical attribute to document.

- **Bulk Density:**

The bulk density measures the heaviness of flour. It is typically influenced by the size of the particles and the density of the flour. Bulk density is crucial for determining packaging requirements,material handling, and use in wet processing in the food industry. Studies found bulk densities of 0.5g/ml, 0.50g/ml, and 0.6g/ml in native, malted, and hydrothermallytreated finger millet seed coat, respectively. The water solubility index (WSI) of finger millet flour differed significantly at 7.73%. This difference could result from the high starch content and low protein and fatcontents in finger millet. Research has shown that protein and fat amounts can prevent starch granule swelling.

- **Foaming Capacity (FC):**

The abilityof a protein to generate foam and the amount of air-water interface createdis referred to as foaming capacity (FC). Foam stability (FS) denotes theprotein's effectiveness to maintain thefoam structure against gravitationaland mechanical forces. The foaming capacity of finger millet flour wasfound to be 1.96%. Both finger milletflours exhibited low foaming stabilityof 0.98 ml. In fact, the flour foam lacked stability over time. This couldbe attributed to protein denaturation during grinding. It is known that native proteins confer higher foamstability compared to denaturedproteins. Furthermore, the low or absent foaming capacity of certainmeals could impact their stability during storage.

- **Dough Characteristics:**

The milletflour that had the hulls removed (50 g with 14% moisture content) wascombined with 35 ml of cold water (30 degrees C).

The properties of the dough were documented in a Brabender farinograph (AACC, 2000) in terms of water absorption, mixing patterns, time for dough development, water uptake and stability.

However, for the millet flourthat still had the hulls, the farinograms were documented separately after mixing the flour withcold water (30 degrees C) and also hotwater (90 degrees C).

- **Cooking Time:**

About 10 grams of peeled millet kernels were placed in 100 milliliters of boiling water in a beaker, and heating continued. Every 30 seconds, a few grains were removed from the beaker andsqueezed between two glass slides.

The spread ability and transparency of the squeezed grains were observedby shining a light from below. The time taken to reach a constant spreaddiameter and complete transparency was considered the cooking time.

4.3.2 Minor Millet

A. Little Millet:

Little Millet (*Panicummiliare*) is cultivated acrossIndia and is a longstanding crop. It is related to proso millet; however, the seeds of little millet are far smaller than those of proso millet. It is also referred to as Moraiyo, Kutki,Shavan, and Sama.

It is abundant in vitamin B and key minerals like Calcium, Iron, Zinc, and Potassium. Little Millet is widely utilized in the Southern Indian states in many conventional dishes. It is a more nutritious alternative to rice and doesnot lead to weight gain**.**

Table 4.4: Nutritional Composition of Little Millet (Nutrient Per 100g)

Protein(g)	7.7
Fiber(g)	7.6
Minerals(g)	1.5
Iron(mg)	9.3
Calcium (mg)	17

a. Functional Properties of Little Millet:

The functional characteristics of little millet grains were also assessed, and the results obtained fromvarious researchers indicate that the grains have good functionalproperties in terms of bulk density, oil absorption capacity, water absorption capacity, minimum gelatinizationtemperature and other qualities.

- **Water absorption capacity &oil absorption capacity (WAC&WOC)**The method used by **Chandra, Singh,and Kumari (2015)** was followed withsome modifications to determine the water and oil absorption capacities ofthe flour samples. For measuring water absorption, 0.83 g of sample was dispersed in 10 mL of distilled water in centrifuge tubes. Thedispersion was stirred occasionally,held for 30 minutes, and then centrifuged at 3000 rpm for 25minutes. The supernatant was pouredinto petri dishes, and excess waterwas removed from the tubes. The sediment was placed in a hot air oven at 50°C for 25 minutes, after which the sample was reweighed. For oilabsorption capacity, 0.5 g of sample was mixed with 6 mL of soybean oil and centrifuged at 3000 rpm for 25 minutes. After centrifugation, theseparated oil was removed using apipette, and the tubes were inverted for 25 minutes to allow the oil to drainbefore reweighing. The water and oilabsorption capacities were expressedin grams of water or oil bound per gram of sample on a dry basis.
- **Least gelation concentration:** The minimum gelling concentration of thesamples was determined by using a modified version of the method described by **Kaushal, Kumar, andSharma (2012).** The sample (5 mL) was prepared at different concentrations (2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 g/100 mL) and placed in test tubes. The test tubes were

heated for 1 hour at 98°C in a water bath, then quickly cooled under running tap water. They were furthercooled at 4°C for 2 hours. The minimum gelling concentration was defined as the lowest concentration atwhich the sample did not flow or slipwhen the test tubes were inverted.

- **Foaming capacity and foaming stability:** The ability of the flours to foam was evaluated using a slightly altered method described by **Maninder et al. (2007).** A 1.5 g flour sample was blended with 50 mL of distilled water and homogenized using a homogenizer (Servodyne, Model 50000-25) set to 960 rpm for 3 minutes. The homogenized mixturewas then poured into a graduated cylinder, and the homogenizer cupwas rinsed with 10 mL of distilled water which was also added to the cylinder. The volume was recorded before and after whipping.
- **Pasting Properties:** The pasting properties of the flours were examined using the rapid visco analyzer (RVA) method described by **Nasrin et al. (2015).** A 2.5 g flour sample was put into the canister and thoroughly combined with 25 mL of distilled water. The flour suspension was heated to 50°C for 1 minute, then the temperature was gradually raised to 95°Cover 3.2 minutes and finally lowered again to 50°C. All flour samples were mixed and homogenized at 960 rpm during the entire test, which lasted 13 minutes in total.
- **Bulk density:** The bulk density of flours was determined by the methoddescribed by **Medhe et al. (2019)** withsome small changes. The flour samples were carefully poured into 10mL graduated cylinders. The bottom of each cylinder was lightly tapped multiple times until the level of the flour stopped going down after fillingto the 10 mL mark. Bulk density was figured out by taking the weight of theflour sample divided by the volume ofthe sample (g/mL).

B. Foxtail Millet:

Foxtail millet is a resilient crop that can tolerate high temperatures and flourish in harsh, desert environments.

This plantgrows quickly; it requires less than 12hours of sunlight every day to thrive. Because foxtail millet contains a lot of carbs, it helps control blood sugar levels.

It contains a lot of iron as well.Malnutrition can be warded off and general immunity strengthened by foxtail millet. Its high potassiumcontent makes it possible for the muscles and brain to functionproperly, which is essential for kidney and brain health.

Table 4.5: Nutritional Composition of Foxtail Millet (Nutrient Per 100g):

Protein (g)	12.3
Fiber(g)	8
Minerals (g)	3.3
Iron (mg)	2.8
Calcium(mg)	31

a. Functional Properties of Foxtail Millet:

- **Bulk Density (BD):**

The bulk densityof the flours in milled fractions. The highest and lowest bulk density is seen in polished and whole grain millet flours, respectively. Flourswith a lower bulk density could be utilized in the preparation of weaningfood formulations.

- **Nitrogen Solubility:**

The nitrogen solubility of millet flours ranges from 2.96 to 16.35 mg/g in water and 4.73 to 16.96 mg/g in 0.5 M NaCl. The solubility of the proteinincreased in 0.5 M NaCl compared to water for all milled fraction flours. The highestnitrogen solubility is seen in brown grain flours. Although proso millet flours have higher protein content, their nitrogen solubility is lower than foxtail millet flours inboth water and NaCl, indicating a highercontent of hydrophobic amino acids in prosomillet flours.

The polished grain floursexhibit the lowest nitrogen solubility in bothmillets, aligning with earlier reports by **Lorenz et al. (1980)** showing that millet protein solubility and digestibility are low atneutral pH. These millet-based formulations may be useful in formulating protein- restricted diets, where low protein intake is preferred.

- **Water Absorption Capacity (WAC), Water Solubility Index (WSI) and Oil Absorption Capacity (OAC):**

WAC is important property of protein and other components of flour in viscous foods, e.g., soups, dough, custards and baked products, because these are supposed to imbibe water without dissolution of protein, thereby providing body, thickening and viscosity.

The water solubility index (WSI) of the fractioned millet flours displays a comparable trend, with the whole grain flours of foxtail millet varieties having the highest values (39.2 and 38.4 mg/g).

However, the WSI of foxtail millet flour is superior to that of its refined flour. This difference may be attributed to variances in the polysaccharide composition. The oil holding capacity (OAC) of the milled portions of the millets ranges from 59.5 to 95.6 g/100 g. The whole grain flour of foxtail millet has the highest OAC values at 91.1 and 90.8 g/100 g. The lowest OAC values are seen in the polished grain flours.

This could be because lipid binding depends on the surface availability of hydrophobic amino acids **(Sosulski et al., 1976)**. A food material's oil absorption capacity is important since it relies mainly on its ability to physically trap oil through a complex capillary attraction process. Oil acts as a flavor retainer provides a consistent texture and enhances mouthfeel **(Khattab & Arntfield, 2009)**. The whole grain flours with the highest OAC may have the potential for use as an ingredient in emulsion-type meat products.

- **Least Gelation Concentration (LGC):**

The capacity of starch to readily form a gel whenheated is a desirable attribute in food industries, especially in products like jams and jellies **(Adebowale, Afolabi, & Olu-Owolabi, 2005).** However, a low concentration is preferred so as not to alter the properties of other ingredients used. Boththe foxtail millet flours demonstrate goodgelling properties.

The foxtail millet exhibitsgelation at 9% flour concentration, while thePS-4 variety of foxtail millet shows gelling at 11% flour concentration. Gel formation occurs primarily due to swelling and hydration of starch granules mainly in the amorphous region of starches.

The strength of the gel depends on intra-granular binding forces within swollen starch granules following heat, moisture treatment and annealing, structural reordering and realignment of amylose and amylopectin.

- **Foaming and Emulsifying Properties:**

Foam formation and stability are usually reliant on the interfacial film made by proteins, which keeps the air bubbles suspended and decreases the rate ofcoalescence. Stable foams happen when thereis low surface tension and high viscosity at the interface, making a continuous cohesive film around the air pockets in the foam. Foaming characteristics depend on the proteins and other components like carbohydrates present in the flour.

C. Barnyard Millet:

Barnyard Millet is a well-known type of millet that is also called Sanwa. It contains high levels of dietary fiberwhich can help improve digestion and promote weight loss. Barnyard Millet is abundant in calcium and phosphorus,minerals that can boost bone health. This grain is commonly used for human consumption and as fodder for animals.

Table 4.6: Nutritional Composition of BarnyardMillet (Nutrient Per 100g):

Protein(g)	11.2
Fiber(g)	10.1
Minerals(g)	4.4
Iron(mg)	15.2
Calcium(mg)	11

a. Functional Properties of Barnyard Millet:

Functional Properties of Barnyard Millet: The functional characteristics including bulk density, swelling power, solubility, solid loss, water absorption capacity and oil absorption capacity were examined using standard procedures in triplicates.

The bulk density of each sample was determined following the method outlined by Ige et al. The swelling power, solubility and solid loss of the raw and processed millet flours were measured using the modified procedure of **Shin et al. (2010).** The water and oil absorption capacities were determined using the method described by Lin et al.

- **Bulk Density:**

The density of the processed barnyard millet flours was shown. Density isa key factor that determines the packaging needs of a product. Compared to the rawmillet flours, the density of the boiled, pressure cooked, and roasted samplessignificantly increased ($p < 0.05$). However, the density of the germinated barnyard milletflours decreased.

The lower density of the germinated millet flour indicates lessporosity or air spacing in the flour, thus less autooxidation. This is beneficial for spoilage,packing, and transportation of goods per unitweight.

- **Swelling power:**

Swelling and water retention abilities are crucial factors in determining a sample's consistency (solid,semi-solid, or liquid) and rely on the compositional makeup of the sample. The swelling capacity of the raw and processed barnyard millet flours was examined. Theswelling capacity of the two processed milletflours at 90°C was consistently lower compared to the raw samples and did not varysignificantly between each other ($p > 0.05$). Swelling behavior below 16 g/g is consideredhighly limited. This restricted swelling behavior of the flour samples indicates stability against shearing forces when heated. Therefore, in this study, the raw and processed barnyard millet flours exhibitedlimited swelling behavior, suggestingresistance to heating.

- **Solubility behavior:**

The solubility of starchgranules after cooking demonstrates theextent to which they have dispersed. Thesolubility characteristics of raw and processed barnyard millet flours at 90°C were shown. Of all the processing methods for the two selected millets, germinated millet flour had the highest solubility.

Solubility can indicate the quantity of amylose that leaks out from the starch granule during swelling, so higher solubility corresponds to more amylose release. Variations in solubility could also be due to differences in the chain length distribution within the starch. **Solid loss:** The barnyard millet raw and processed flours showed solid loss.

The processed barnyard millet flour displayed solid loss to the degree of 27.9% in boiled, 26.5% in germinated, 29.1% in pressure cooked, 30.1% in roasted and 30.7% in unprocessed samples. A noteworthy increasein solid loss was seen in the barnyard millet flours ($p < 0.05$).

- **Water absorption capacity (WAC):**

Thestudy presented the water absorption capacityof raw and processed barnyard millet flours. Water absorption capacity is important for developing ready-to-eat foods, as high absorption capacity can ensure product cohesion.

The variations in water absorptioncapacity of processed barnyard millet are largely due to factors like the number ofhydration sites, physical environment, pH, solvent, and the presence of lipids and carbohydrates. In this study, water absorptioncapacity significantly increased ($p < 0.05$) inboiled, pressure cooked and roasted samplescompared to raw samples, but germinatedbarnyard millet flours had the lowest water absorption capacity. When flour has high lipid content, water absorption decreases because lipids block the polar sites ofproteins, attenuating water absorption.

- **Oil absorption capacity:**

The raw and processed barnyard millet flours were analyzed for their ability to absorb oil. The high oil absorption capacity makes these flours useful for improving flavor and mouthfeel when used in food products.

Oil absorption capacity significantly increased ($p < 0.05$) in the boiled, germinated, pressure cooked and roasted millet flours compared tothe raw samples. The differences in fat absorption may be attributed to variations in protein content, interactions with water and oil, and conformational properties.

D. Kodo Millet:

Kodo Millet, which is also referred to as Kodon Millet, is a highly digestible type that has high levels of the amino acid lecithin. It has a considerable impact on reinforcing the nervous system. Kodois an excellent source of B vitamins, particularly niacin, B6, and folic acid,as well as other vitamins and minerals.

It contains the minerals calcium,iron, potassium,magnesium, and zinc. Since it is a gluten-free millet, it is great for people who cannot tolerate gluten. It can alleviate cardiovascular conditions like high blood pressure and cholesterol when consumed. regularly by women who have gonethrough menopause.

Table 4.7: Nutritional Composition of Kodo Millet (Nutrient Per 100g):

Protein (g)	8.3
Fiber(g)	9
Minerals (g)	2.6
Iron (mg)	0.5
Calcium (mg)	27

Functional properties of Kodo millet: The bulk density, true density, moisture content, water absorption index, water solubilityindexes, expansion index and viscosity of thedough and/or extrudate are importantphysical properties. These physicalcharacteristics are crucial in choosing extruded food for a specific use.

- **Hydration capacity:** The average water absorbing ability of the seeds was 1.81±0.57 grams per 1000 seeds, with a hydration percentage of 34.98±0.31 percent.
- **Swelling capacity:** The swelling ability of the grain was 1.2±0.1 milliliters per 1000 seeds, and the swelling index was 31.8±0.62.
- **Cooking quality:** The cooking time and texture of the grain are important factors in determining consumer acceptance. The kodomillet grains took 14 minutes to become fully cooked. After cooking, the weight andvolume were 308.93±0.45 grams and 349.66±0.57 milliliters, respectively.

E. Proso Millet:

Proso millet is high in proteins, vitamins, minerals, dietary fiber, and polyphenols. Because it is gluten-free, it is perfect for those whoare intolerant to gluten. High levels oflecithin in Proso millet help the neurological health system. It is abundant in minerals (P, Ca, Zn, Fe), vitamins (niacin, B-complexvitamins, folic acid), and important amino acids (methionine and cysteine).

Table 4.8: Nutritional composition of Proso Millet (nutrient per 100g):

Protein(g)	12.5
Fiber(g)	2.2
Minerals (g)	1.9
Iron(mg)	0.8
Calcium (mg)	14

Functional properties of Proso millet: Functional properties of prosomillet are following based on their different properties:

- **Bulk density (BD):** The flour bulk density was determined by employingthe procedure described by **Okezieand Bello (1988).** It was computed as the mass of the sample per unitvolume of the sample (g/l).
- **Nitrogen solubility:** The level of soluble nitrogen in millet flours was measured in distilled water (pH 7) and 0.5 N NaCl (pH 7). The quantity of protein in the supernatant was quantified by utilizingthe Pierce bicinchoninic acid (BCA) protein assay kit from Thermo Scientific (Rockford,Illinois, USA). The soluble protein was reported in mg per g of flour sample.
- **Water Absorption Capacity (WAC), Oil Absorption Capacity (OAC) and Water Solubility Index (WSI):** The water absorption capacity (WAC) and oil absorption capacity (OAC) of the millet flourwere measured by following the methodsdescribed by **Elhardallou and Walker (1993) and Sosulski, Humbert, Bui, and Jones (1976),** respectively. The results were reported as grams of water/oil absorbed per 100 grams

of the dry flour. The water solubility index (WSI) was determined usingthe procedure outlined by **Anderson, Conway, Pfeifer, and Griffin (1969).** It was calculated from the ratio of the weight of dissolved solids in the supernatant to the weight of the dry sample.

- **Foaming and emulsifying properties:**Foam capacity (FC) and foam stability (FS) were tested by the method described by **Coffmann and Garcia (1977).** The amount of foam produced was recorded as foam capacity, and the volume was monitored at regular time intervals for 60 minutes to assessstability. Emulsion activity (EA) and emulsion stability (ES) were measured usingthe procedure outlined by **Yasumatsu et al. (1972).**
- **Gelation:** The gel formation was assessed using the technique of **Sathe and Salunkhe (1981).** Some modifications were made by preparing millet flour suspensions at concentrations of 1-15% (w/v) in 1% increments. The minimum gelling concentration was determined to be the concentration where the sample did not flow when the test tubes were turned upside down.

4.4 References:

1. Adebowale, K. O., Afolabi, T. A., & Olu-Owolabi, B. I. (2005). Hydrothermal treatments of Finger millet (Eleusine coracana) starch. *Food Hydrocolloids*, *19*(6), 974-983.
2. Anderson, R. A., Conway, H. F., Pfeifer, V. F., & Griffin, E. L. (1969). Roll and extrusion-cooking of grain sorghum grits. *Cereal Science Today*, *14*(11), 372-376.
3. Chandra, S., & Samsher, S. (2013). Assessment of functional properties of different flours. *African journal of agricultural research*, *8*(38), 4849-4852.
4. Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of food science and technology*, *52*, 3681-3688.
5. Coffmann, C. W., & Garciaj, V. V. (1977). Functional properties and amino acid content of a protein isolate from mung bean flour. *International Journal of Food Science & Technology*, *12*(5), 473-484.

6. Elhardallou, S. B., & Walker, A. F. (1993). The water-holding capacity of three starchy legumes in the raw, cooked and fibre-rich fraction forms. *Plant Foods for Human Nutrition*, *44*, 171-179.
7. Kaushal, P., Kumar, V., & Sharma, H. K. (2012). Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (Colocasia esculenta), rice (Oryza sativa) flour, pigeonpea (Cajanus cajan) flour and their blends. *LWT-Food Science and Technology*, *48*(1), 59-68.
8. Khattab, R. Y., & Arntfield, S. D. (2009). Functional properties of raw and processed canola meal. *LWT-Food Science and Technology*, *42*(6), 1119-1124.
9. Lorenz, K., Dilsaver, W., & Bates, L. (1980). Proso millets. Milling characteristics, proximate compositions, nutritive value of flours. *Cereal Chem*, *57*(1), 16-20.
10. Maninder, K., Sandhu, K. S., & Singh, N. (2007). Comparative study of the functional, thermal and pasting properties of flours from different field pea (Pisum sativum L.) and pigeon pea (Cajanus cajan L.) cultivars. *Food chemistry*, *104*(1), 259-267.
11. Medhe, S., Jain, S., & Anal, A. K. (2019). Effects of sprouting and cooking processes on physicochemical and functional properties of moth bean (Vigna aconitifolia) seed and flour. *Journal of food science and technology*, *56*, 2115-2125.
12. Nasrin, T. A. A., Noomhorm, A., & Anal, A. K. (2015). Physico-chemical characterization of culled plantain pulp starch, peel starch, and flour. *International Journal of Food Properties*, *18*(1), 165-177.
13. Okezie, B. O., & Bello, A. B. (1988). Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. *Journal of Food science*, *53*(2), 450-454.
14. Sathe, S. K., & Salunkhe, D. K. (1981). Functional properties of the great northern bean (Phaseolus vulgaris L.) proteins: emulsion, foaming, viscosity, and gelation properties. *Journal of food science*, *46*(1), 71-81.
15. Shin, M., Gang, D. O., & Song, J. Y. (2010). Effects of protein and transglutaminase on the preparation of gluten-free rice bread. *Food Science and Biotechnology*, *19*, 951-956.
16. Sosulski, F., Humbert, E. S., Bui, K., & Jones, J. D. (1976). Functional propreties of rapeseed flours, concentrates and isolate. *Journal of Food science*, *41*(6), 1349-1352.

17. Yagoub, A. A., & Abdalla, A. A. (2007). Effect of domestic processing methods on chemical composition, in vitro digestibility of protein and starch and functional properties of bambara groundnut (Voandzeia subterranea) seed. *Research Journal of Agriculture and Biological Sciences*, *3*(1), 24-34.
18. Yasumatsu, K., Sawada, K., Moritaka, S., Misaki, M., Toda, J., Wada, T., & Ishii, K. (1972). Whipping and emulsifying properties of soybean products. *Agricultural and Biological Chemistry*, *36*(5), 719-727.
19. Holse, J. H., Laing, E. M., & Pearson, O. E. (1980). *Sorghum and the millets: their composition and nutritive value*. Academic press.
20. ICMR-NIN Expert Group on Nutrient Requirement for Indians, Recommended Dietary Allowances (RDA) and Estimated Average Requirements (EAR)- (2020)
21. Ambati, K., & Sucharitha, K. V. (2019). Millets-review on nutritional profiles and health benefits. *International Journal of Recent Scientific Research*, *10*(7), 33943-33948.