A Brief Review on Millet Starch

Smita Dimri, Sukhcharn Singh

10.18805/BKAP489

ABSTRACT

The popularity of millet and its products is growing worldwide due to its health-promoting characteristics. The starch in millet is the most essential element, accounting for around 70% of total millet-grains and determining the quality of food items based on millets. The structural, functional and physicochemical features of starch determine its use for various purposes. Natural starch does not have the characteristics needed for specific purpose. Modifications in the structures of starch can be used to get product-specific properties. Information gaps on millet starch has hindered its potential use in new food product design. The objective of the review is to investigate and examine the structural chemistry, characterization, chemical composition and modification methods of the millet starches.

Key words: Amylose, Major millet, Millet starch, Minor millet, Starch modification.

Millets is a term that generally refers to the group of grains having small seeds that belong to the Chlorideae and Paniceae tribes of family Poaceae. Before the emergence of wheat and rice, it was already the primary food for human civilization 10,000 years ago, Zhang *et al.* (2009). Millets are classified into 2 types, major and minor. The major millets include Proso millets (*Panicum miliaceum*), pearl millets (*Pennisetum glaucum*), foxtail millets (*Seratia italica*) and finger millets (*Eleusine coracan*). The minor millets include, little millet (*Panicum miliare*), barnyard millet (*Echinochloa* spp), kodo millet (*Paspalum scrobiculatum*), white fonio millet (*Digitari aexilis*), black fonio millet (*Digitari aiburua*) and teff millets (*Eragrostis tef*), Marcone *et al.* (2014).

Millets may be rich in minerals such as iron and calcium, B-vitamins, phosphorus in the form of phytic acid, dietary fiber, polyphenols and lipids, Saleh *et al.* (2013). Millets may aid individuals with celiac disease as they lack gluten. Millets decrease the levels of blood glucose, making them an effective product against diabetes. Due to their bioactive and nutritional qualities, millets are possible candidates for a variety of functional foods that might delay or prevent the emergence of non-communicable diseases, Dixit *et al.* (2011). Millets, in addition to their nutritional qualities, have a shorter cultivation time, require less water, are more adaptable to harsh climatic condition and produce more on marginal areas than major cereal crops, Kumari and Singh (2015). Millets thrive in semi-arid parts of Asia and Africa due to their agro-climatic requirement when other major crops fail, Belton *et al.* (2004). However, millets are cultivated, produced and consumed differently in distinct parts of the world. For example, China primarily cultivates foxtail millet, whereas India, Nepal and Africa primarily cultivate pearl millet and North America primarily cultivates proso millet, Obilana (2003).

Nutritional composition

Millets are rich in dietary fibre, phytochemicals and micronutrients, Dayakar *et al.* (2017). They are fairly good source of proteins. In-fact the amino acid profile of millets is much better than the most common cereals. However they are low in lysine. The typical composition is as follows: carbohydrates 65-75%, dietary fibre 15-20%, protein 7-12% and fats 2-5%. Millets are also known to have some antioxidant properties due to presence of phytates, polyphenols, tannins, phytosterols, anthocyanins, *etc.*

Starches of millets

Starch is made up of 2 primary molecular components: amylopectin and amylose. Depending on the type of fractionation, an intermediary structural component may be provided. Amylose is linear having several branches, α-(1-6) linkage, dispersed throughout the linear backbone, α-(1-4) linkage, while amylopectin has a significantly larger number of branches. The molecular structure of starch components is linked to their production, physical granular structures, functioning and possible application, Srichuwong *et al.* (2007).

Millet starch composition

Millets, like other grains, contains 51 to 79 per cent starch. The starch content of pearl and finger millets ranges from 71 to 81 per cent and 51 to 69 per cent, respectively. Millet starches typically comprise between 70 to 80 per cent amylopectin and 20 to 30 per cent amylose. The inclusion of additional elements as impurities in starch granules has a substantial impact on their functioning. Millet starches, for

Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Deemed University, Longowal, Sangrur-148 106, Punjab, India.

Corresponding Author: Smita Dimri, Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Deemed University, Longowal, Sangrur-148 106, Punjab, India. Email: gairolasmita@gmail.com

How to cite this article: Dimri, S. and Singh, S. (2022). A Brief Review on Millet Starch. Bhartiya Krishi Anusandhan Patrika. 37(2): 126-132. DOI: 10.18805/BKAP489.

Submitted: 12-03-2022 **Accepted:** 19-05-2022 **Online:** 09-06-2022

example, are mostly composed of polar phospholipids (89 per cent), with rest composed of nonpolar lipids, primarily triglycerides. Because of their cohesive nature and hydrophobic interactions, these lipids form complex with the amylose component of starch and may impair the flowability and swelling capacity of starch. Protein has both hydrophobic and hydrophilic bonds, which influence its oil and water binding capabilities. The fibres are known to decrease uptake of oil, which may impair oil binding ability. Polyphenols' influence on millet starch functioning has yet to be documented. However, the effect of adding polyphenols from external sources, such as vanillic acid, gallic acid and quercetin to starch and their influence on many physicochemical aspects have been extensively studied. For example, with the addition of pomegranate peel extract, the maximum viscosity of wheat starch increases. In addition, black tea extract was shown to be more efficient than green tea extract in decreasing the cold paste viscosity of wheat, rice, maize and potato starch, Mahajan *et al.* (2021).

XRD diffraction pattern

Like other starches, starches of millet are semicrystalline, such that, they have both the crystalline and amorphous region. Diffraction patterns of millet species are characteristic of A-type polymorphs, Kim *et al.* (2011). The relative crystallinity of the various millet starches is 24% in pearl millets, 25% in foxtail millets, 25% in finger millets, 26% in Japanese barnyard and 31% proso millets, Wu *et al.* (2014). Millet starch contains A-Type crystal pattern having 4 characteristic peaks: single peak at 2θ value of 23°, sharp peak at 2θ value of 15° and the double peaks at 2θ value of 17° and 18°, Kim *et al.* (2012). The inclusion of certain impurities in starch, on the other hand, causes changes in the peaks and decreases their intensities by increasing the amorphous area in relation to the crystalline section. The degree of crystallinity is determined by the differences in the types of starch granules. Amylose deficiency enhances crystallinity while having no effect on the size of granules, Yoo *et al.* (2002). Longer chain of amylopectin have a steadier crystalline structure than shorter chain, which are readily disrupted when heated to high temperatures. Type-A starch granule contains more amylose compared to B-type granules, resulting in a low crystallinity percentage in type-A starch granules, Ao *et al.* (2007). Milling and other food processing methods, result in modification by altering the physical structures of starch granules. The crystalline-amylopectin fractions convert into amorphous amylopectin when a few low - molecular weight fractions form. The degree of crystallinity of starch granules affects the overall function of food.

Properties of millet starch

Swelling, solubility and water absorption capacity

In the presence of heat and water, granules of starch enlarge by absorbing water. Millet starch exhibit swelling power in 50 to 90°C temperature range. Millet starches were shown to have a lower swelling power than rye, wheat and potato starch, Hoover (2001). This concludes that millet starches are more resistant to swelling because of their comparatively high bonding force between granules. The starch granules having short amylopectin chains may readily bind water molecules by hydrogen bonds; but amylose and its lipid complexes and long amylopectin chain create helical boundaries and it hinders the entrance of molecules of water, Suma *et al.* (2015). As a result, low amylose starches may readily find food application where there is a necessity of viscosity, like thickening agent present in soup. Furthermore, the existence of amylose is advantageous in goods that need retrogradation.

The water absorption index of starch-based flour while heating may also be associated to swelling capacity. The porous structure of starch polymers is associated to its high-water absorption capacity, while low values show the structure's compactness, Adebowale *et al.* (2012). There is a substantial variance in the water absorption index, which ranges from 0.77-1.22g per g.

Pasting behaviour

Many factors influence the pasting behaviour of starch and its characteristics, including starch composition, concentration, cooling and cooking temperatures, as well as the presence of solutes such as sugar, lipid and pH. Waxy starches may readily bind with water and swell quickly, achieving their peak pasting temperatures in relatively short period of time, Moita *et al.* (2008). While analysing the pasting properties of different millet starch, the barnyard millet starch had the lowest breakdown viscosity (BDV) *i.e.*, 20 Brabender units and peak viscosity of 375 Brabender units, whereas the proso millet starch had the maximum peak viscosity of 520 Brabender units and breakdown viscosity of 20 Brabender units. Both barnyard and Kodo millet starch had higher SBV (setback viscosity) than proso millets, Kumari *et al.* (1998). Setback viscosity shows the tendency of starches to retrograde after its cooling and gelatinization. Even within the same species, there has been a lot of variation in pasting profiles. Pasting characteristics, on the other hand, are important for the progression and production of commercial RS (resistant starches), as well as their additional uses including gelling agents and thickeners.

Thermal properties

The properties of starch gelatinization differ not only across millet species, but also between genotypes within the same species. They are affected by amylose-amylopectin ratio and size of starch granules, Mahajan *et al.* (2021). The high gelatinization temperature indicates more energy is required to initiate starch gelatinization, which is also attributed to the arrangement of amylopectin crystals, Bhupender *et al.* (2013). The gelatinization temperature (To) in descending order was: proso millet (68.4°C)>foxtail millet (66.7°C)>finger millet (63.9°C)>pearl millet (62.8°C). The enthalpy (ΔH) of millet starches was found as finger millet (13.2 J/ g)>proso millet (13.1 J/g)>pearl millet (12.3 J/g)>foxtail millet (11.8 J/g). The peak gelatinization temperatures (Tp) for the pearl millet starch varied from 67.5°C to 76.4°C and ΔH from 8.5-14.7 J/g. Tp and ΔH for proso millet starch vary respectively as 57-80.2°C and 6.4-14.9 J/g. Similarly, Tp and ΔH ranged respectively as 54°C-75°C and 8.2-16.3 J/g for foxtail millet starch, Mahajan *et al.* (2021). The higher value of ΔH indicates a stronger bonding which corresponds to the heat required to break the inter-molecular bonding, Mahajan *et al.* (2021).

Isolation of starch from millets

Starch may be extracted using a variety of physical, chemical, enzymatic processes such as filtering, gravity sedimentation and centrifugation, Jane (2009). Every starch differs from the other in their structural and physiochemical properties, depending on the origin and variety. Starch granules are firmly linked with protein-matrix of grains. Various techniques are employed for solubilizing the protein content to extract starch from grains, Halal *et al.* (2019). Wet-milling techniques have been used to separate starch from millets. In general, there are three processes of starch extraction; anatomic fragmentation, cell rupture and starch purification. Before milling, whole millet kernel (flour) is steeped in aqueous solution for few hours to aid in the separation of starch from other elements. The slurry is then rinsed and filtered several times to eliminate fibrous component and proteins. Before drying, the starch is separated by centrifugation, Kumari *et al.* (1998). Selection of solution for the extraction of starch from the millets depend upon their properties and chemical compositions. It is critical to choose a technique that produces a higher starch content with low protein residues. In comparison to the alkaline technique (0.7%), the acidic steeping technique yields high protein residue (4.3%) in granules, Yanez *et al.* (1986). Alkali isolation technique is the most well-known approach, which was introduced by Dimler *et al.* (1944) and it allows for simple extraction of associated proteins (Fig 1).

Modification of millet starch

Millets are used to make a variety of foods and beverages, including fermented and non-fermented flatbread, porridge, non-alcoholic beverages and beer, Amadou (2011). Quality and production of these products largely depends on the structures, properties, composition and interaction of starch. In its natural form, starch does not possess those chemical and physical properties that are otherwise required for a specific use. However, their modification affects a number of properties, which makes them appropriate for their use in both non-food and food sectors, Egharevba (2019). Furthermore, the modification improves its functional properties, providing resistant starch for their use in functional food products. Briefly, it opens up possibilities for its uses. It could be accomplished by enzymatic, chemical and physical techniques, as well as hybrids of these techniques. Modification of starch is typically accomplished by derivatization (cross-linking, etherification, esterification), by decomposition (starch oxidation and acid hydrolysis), physical treatments (ultra-high pressure, heat moisture), or enzymes, Kaur *et al.* (2012). Several modification procedures and their effects on millet starches are discussed as follow:

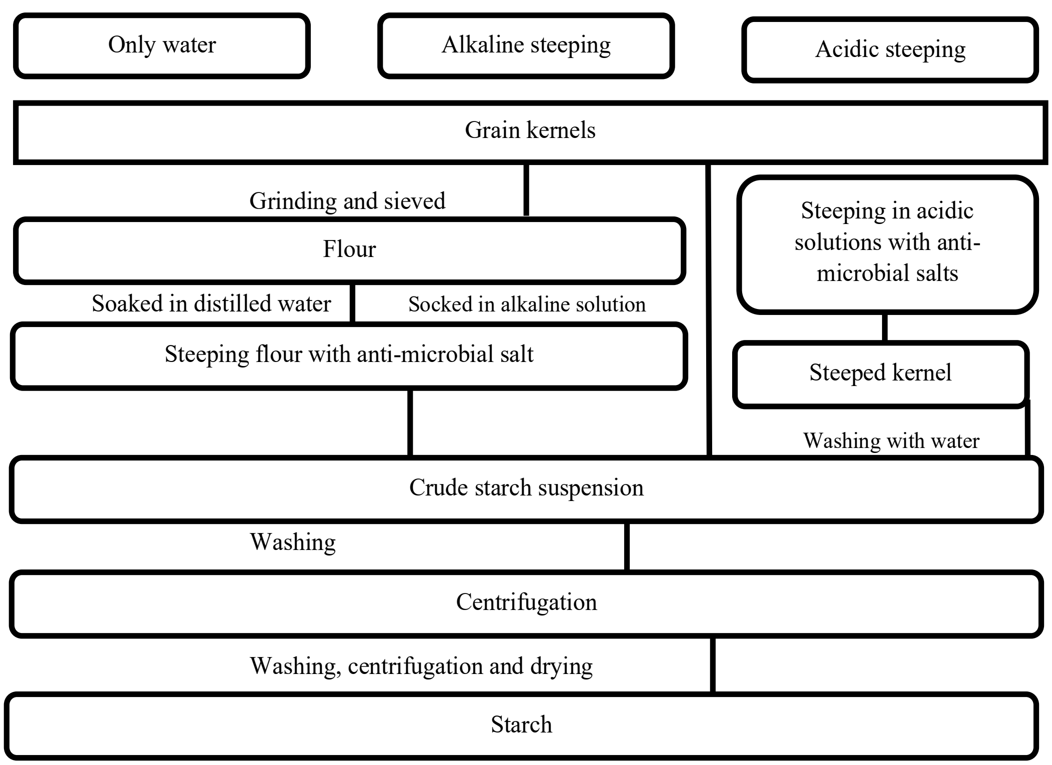

Fig 1: General procedures of starch isolation.

Modification by hydrothermal treatment

Hydrothermal treatment, also known as heat-moisture treatment (HMT), is a physical modification technique which includes the application of regulated moisture and heat. The procedure performs effectively with low moisture levels (less than 35 per cent moisture w/w) and the temperature more than gelatinization temperature for 15 minutes to 16 hours, Arns *et al.* (2014). By partially altering the crystalline structure, it affects the interactions between polymer chains. As a result, the double-helical structure dissociates and the fragmented crystals are rearranged in the end, Gunaratne *et al.* (2002). The impact of heat moisture treatments on enzyme digestibility of starch is primarily determined by (a) starch source, (b) moisture content, (c) temperature and treatment time and (d) interactions between starch fraction amylopectin-amylopectin, amylose-amylose and amylose-amylopectin, Zeng *et al.* (2015).

Enzymatic modification

Use of enzymes for the modification of starch is generally recognized and practiced since it eliminates the use of chemicals. These enzymes break down delicate starch granules, causing numerous microscopic holes to form on the granule's surface. This reduces the suspensions' viscosity and water holding capacity, Cornejo-Ramirez *et al.* (2018). Modification by enzyme degrades amylose into lower molecular weight oligosaccharide in starch with a high amylose concentration. This modification approach yields amylopectin and amylose that are highly branched, which combines and forms a starch having decreased digestibility and increased water-solubility, both of them are ideal for beverage industry. More amylose chains form as a result of this treatment, restricting water absorption and reducing the swelling potential of starches. Enzymatically treated starch showed decreased syneresis and better transmittance, Balasubramanian *et al.* (2014). Properties such as freeze-thaw stability, colour value, paste clarity and the pasting behaviour of starch is shown to have enhanced; which may be due to improved intra-molecular and inter bonding of starch chains giving it better structural stability. This sort of behaviour is essential to achieve the proper product consistency in food items such as paste and jellies.

Table 1: Applications of millet starch.

Source starch	Modified/native starch	Characteristics	Application	Reference
Pearl millets	Native, acid modified and pregelatinized	Water holding capacity and swelling capabilities are enhanced and disintegrant efficiency was improved.	In the manufacture of chloroquine's tablets as a disintegrant	Odeku *et al.* 2007
Pearl millet	A mixture of starch and carrageenan gum	Increased carrageenan and starch concentrations improved film tensile strength while lowering water vapour permeability in composite film.	consumable composite films	Sandhu *et al.* 2020
Foxtail millets	Native	Antioxidant and antimicrobial properties in active packaging materialsUV light protection properties	Packaging film containing clove leaf oil, for queso Blanco cheese	Yang *et al.* 2018
Barnyard millets	Native	Solubility in water, water vapour and moisture levels permeability have all decreased, light barrier and antioxidant abilities.	Edible starch films having oil of borage seed	Cao *et al.* 2017
Finger millets	Oxidized and acetylated	In the instance of modified starch compacts, the reduction in disintegration deformability and time is offset by an increase in tensile and crushing strength.	Formation of a tablet and capsule	Afolabi *et al.* 2012
Pearl millet	Succinylated and hydroxypropylated	Reduced syneresis and enhanced cold storage stability	White sauce	Shaikh *et al.* 2020
Pearl millets	Acetylate and hydroxypropylated	Enhanced flexibility, transparency and water solubility	Biodegradable starch film	Shaikh *et al.* 2019
Teff millets	Pregelatinized	Better compressibility and faster disintegration time	In the preparation of chloroquine phosphate tablet, as a disintegrant	Assefa *et al.* 2020
Pearl millet	Octenyl succinylate	Structural strength and high viscosity	Replacer of fat in low fat ice-creams	Sharma *et al.* 2017
Teff millets	Native	Prevents lipid oxidation, has a strong mechanical and water barrier qualities and has a high radical scavenging action.	Camucamu extract-based antioxidant packaging material	Ju *et al.* 2019

The acid modification approach may be substituted by these enzymatic modification techniques (green technology).

Modification by acid hydrolysis

Acid hydrolysis is a popular and commonly used process for modifying starch. This approach increases the number of short linear chain like amylose by exposing starch to mineral acids (HCl, H_2SO_4, H_3PO_4 and HNO_3) at temperature less than its temperature of gelatinization. It hydrolyses the starch by disrupting glycosidic linkage of α-glucan chain, causing structural and characteristic alteration of the original starch. The rate of hydrolysis varies with the time of treatment, Singh *et al.* (2000). In this mechanism, hydroxonium ion targets oxygen in the glycosidic bond and subsequently hydrolyses the linkage. The acids operate on the surface of the granules before penetrating it, keeping the structure of granules intact. There was a reduction in syneresis, swelling capability and subsequent rise in solubility for acid modified foxtail starch and pearl starch, Dey *et al.* (2017). When compared to the native starch of proso-millet, acid modified starch reduced WBC. This might be attributable to the decreased amorphous area in the acid modified starch, which reduces accessibility to the binding sites. Similarly, the PV and PT of finger millet, the AMS of the native starch was higher, while other pasting properties were lower. It might be attributed to enhanced inter - molecular bonding between the modified linear-starch chain. Acid modified starch also reduced the transmittance of starch of pearl millet during storage, Balasubramanian *et al.* (2014). The biggest downside of this technology is the extensive usage of chemicals, which has a negative impact on the environment.

Such approaches improve starch application by increasing its capacity of water binding and decreasing its syneresis. The modification of starch promises health benefits including digesting resistance, prebiotic activity, colon health, cholesterol and blood glucose level reduction.

Applications

Starch is a multifunctional biomaterial that is utilized in a variety of industries, including textiles, food and pharmaceuticals. The physicochemical and functional characteristics of starch define its desired function or involvement in a specific sector. Millet starch is utilized in the non-food and food industries in both its modified and natural forms. Modified and native starches are commonly used as a thickener, binder and flavor encapsulating agent in baked goods, meat products and snack seasoning, emulsion stabilizers in juices and beverages, gelling agent in gels and gums, as a crisping agent in fried snacks and foam stabilizer in marshmallows. As drug delivery method, acid modified, acetylated, pregelatinized, native starches and esterified are often utilized in tablet formation. Tablets made from corn and millets starches had comparable mechanical qualities and drug/nutrient release properties, whereas pre-gelatinized and/or acid-modified starches had lower dissolving value and disintegration, Assefa *et al.* (2020). Millet starches have a number of uses and functions, as seen in Table 1.

Conclusion

Millets are cultivated in the semi arid areas around the world in which typical cereals have a hard time growing. They have health-promoting properties. Starch is a key component of millets, however unlike other conventional sources, it is underutilised as a raw material for starch production. Millet starches function similarly to other starches as a texture modification, viscosity regulators, structural agents and binders. However, their usage is constrained due to a lack of large-scale availability since production and cultivation are limited to just a few geographical regions throughout the world. Because of its limited functionality, starch is hardly utilized in its natural form and must be modified before use. Starch modification has long been recognised to be efficient in altering the properties of starches. Every modification process contributes differently to change in structure in the starch, which may impact the starch's resistance towards digesting enzymes. When applied singly or in combination, these methods cause changes in structure of the starch. The use of diverse approaches aids in the study of the relation between starch structure and properties; however, they are presently limited. Such data would aid in developing food products that are beneficial to health. In addition to this constraint, several millets, such as whitefonio, blackfonio, Kodo, barnyard, teff and small millet still need to be properly explored for their significant food applications. This would also benefit individuals who consume millet as their main source of nutrients, since it would minimize their dependency on other conventional cereal grains.

References

Adebowale, A.A., Adegoke, M.T., Sanni, S.A., Adegunwa, M.O. and Fetuga, G.O. (2012). Functional properties and biscuit making potentials of sorghum-wheat flourcomposite. American Journal of Food Technology. 7: 372-379.

Afolabi, T.A., Olu-Owolabi, B.I., Adebowale, K.O., Lawal, O.S. and Akintayo, C.O. (2012). Functional and tableting properties of acetylated and oxidised finger millet (*Eleusine coracana*) starch. Starch-Stärke. 64(4): 326-337.

Amadou, I., Gbadamosi, O.S. and Le, G.W. (2011). Millet-based traditional processed foods and beverages-A review. Cereal Foods World. 56(3): 115121.

Ao, Z.J. and Jane, (2007). Characterization and modeling of the a- and b- granule starches of wheat, triticale and barley. Carbohydrate Polymers. 67: 46-55.

Arns, B.R.T., Paraginski, J., Bartz, R., Almeida Schiavon, M.C., Elias, E,. Zavareze, da Rosa and Dias, A.R.G. (2014). The effects of heat-moisture treatment of rice grains before parboiling on viscosity profile and physicochemical properties. International. Journal of Food Science. 49(8): 1939-1945.

Assefa, F., Dilebo, J., Gabriel, T., Brhane, Y. and Wondu, K. (2020). Characterization and tablet property evaluation of pregelatinized starch of teff (*Eragrostis* tef). Asian Journal of Pharmacy. 8(5): 18-23.

Balasubramanian, S., Sharma, R., Kaur, J. and Bhardwaj, N. (2014). Characterization of modified pearl millet (*Pennisetum typhoides*) starch. Journal of Food Science and Technology. 51(2): 294-300.

Belton, P.S. and Taylor, J.R. (2004). Sorghum and millets: Protein sources for Africa. Trends in Food Science and Technology. 15(2): 94-98.

Bhupender, S.K., Rajneesh, B. and Baljeet, S.Y. (2013). Physicochemical, functional, thermal and pasting properties of starches isolated from pearl millet cultivars. International Food Research Journal. 20(4): 1555-1561.

Cao, T.L., Yang, S.Y. and Song, K.B. (2017). Characterization of barnyard millet starch films containing borage seed oil. Coatings. 7(11): 183. https://doi.org/10.3390/coatings7110183.

Cornejo-Ramirez, Y.I., Martinez-Cruz, O., Del Toro-Sanchez, C.L., Wong-Corral, F.J., Borboa-Flores, J. and Cinco-Moroyoqui, F.J. (2018). The structural characteristics of starches and their functional properties. CYTA-J. Food. 16(1): 1003-1017.

Dayakar Rao, B., Bhaskarachary, K., Arlene Christina, G.D., Sudha Devi, G., Vilas, A.T. and Tonapi, A. (2017). Nutritional and health benefits of millets. ICAR-Indian Institute of Millets Research (IIMR): Hyderabad, 112.

Dey, A. and Sit, N. (2017). Modification of foxtail millet starch by combining physical, chemical and enzymatic methods. International Journal of Biological Macromolecules. 95: 314-320.

Dimler, R.J., Davis, H.A., Rist, C.E. and Hilbert, G.E. (1944). Production of starch from wheat and other cereal flours. Cereal Chemistry. 21(5): 430-446.

Dixit, A.A., Azar, K.M.J., Gardner, C.D. and Palaniappan, L.P. (2011). Incorporation of whole, ancient grains into a modern Asian Indian diet to reduce the burden of chronic disease. Nutrition Reviews. 69: 479-488.

Egharevba, H.O. (2019). Chemical Properties of Starch and Its Application in the Food Industry. In Chemical Properties of Starch, IntechOpen.

Gunaratne, A.R. and Hoover (2002). Effect of heat-moisture treatment on the structure and physicochemical properties of tuber and root starches. Carbohydrate Polymers. 49(4): 425-437.

Halal, S.L.M., D.H. Kringel, E.D.R., Zavareze, A.R. and Dias, G. (2019). Methods for extracting cereal starches from different sources: A review. Starch-Stärke. 71(11-12): 1900128.

Hoover, R. (2001). Composition, molecular structure and physicochemical properties of tuber and root starches: A review. Carbohydrate Polymers. 45: 3253-3267.

Jane, J.L. (2009). Structural Features of Starch Granules II, Starch. Academic Press. 193-236.

Ju, K.B. and Song, A. (2019). Development of teff starch films containing camu-camu (*Myrciaria dubia* Mc. Vaugh) extract as an antioxidant packaging material. Ind. Crops Prod. 141. 111737.

Kaur, B., Ariffin, F., Bhat, R. and Karim, A.A. (2012). Progress in starch modification in the last decade. Food Hydrocolloids. 26(2): 398-404.

Kim, S.K., Lee, H.D., Ryu, J.G., Choi, H.J., Kang, S.M. and Lee, I.J. (2011). Physical and structural characteristics of endosperm starch of four local barnyard grass (*Echinochloa crus-galli* L.) collections in Korea. Korean Journal of Crop Science. 56(4): 293-298.

Kim, S.K., Choi, H.J., Kang, D.K. and Kim, H.Y. (2012). Starch properties of native proso millet (*Panicum miliaceum* L.). Agron. Res. 10(1-2): 311-318.

Kumari, S. and Singh, S.K. (2015). Assessment of genetic diversity in promising finger millet [*Eleusine coracana* (L.) gaertn] genotypes department of GPB, RAU, Pusa Bihar, India. 10(2): 825-830.

Kumari, S.K. and Thayumanavan, B. (1998). Characterization of starches of proso, foxtail, barnyard, kodo and little millets. Plant Foods and Humun Nutrition. 53(1): 47-56.

Mahajan, P., Bera, M.B., Panesar, P.S. and Chauhan, A. (2021). Millet starch: A review. International Journal of Biological Macromolecules. 180(13). DOI: 10.1016/j.ijbiomac.2021.03.063.

Marcone, G.A., Bertoft, M., E. and Seetharaman, K. (2014). Physical and molecular characterization of millet starches. Cereal Chemistry. 91(3): 286-292.

Moita, B.C., Louren«o, C.A., Bagulho, A.S. and Beirão-da-Costa, M.L. (2008). Effect of wheat puroindolineallels on functional properties of starch. Eur. Food Res. Technol. 226: 1205-1212.

Obilana, A.B. (2003). Overview: Importance of Millets in Africa, World (all cultivated millet species) 38-28.

Odeku, O.A. and Alabi, C.O. (2007). Evaluation of native and modified forms of *Pennisetum glaucum* (millet) starch as disintegrant in chloroquine tablet formulations. Journal Drug Delivery and Science Technology. 17(2): 155-158.

Saleh, A.S., Zhang, M., Chen, Q.J. and Shen, Q. (2013). Millet grains: Nutritional quality, processing and potential health benefits. Comprehensive Reviews in Food Science and Food Safety. 12: 281-295.

Sandhu, K.S., Sharma, L., Kaur, M. and Kaur, R. (2020). Physical, structural and thermal properties of composite edible films prepared from pearl millet starch and carrageenan gum: Process optimization using response surface methodology. International Journal of Biological Macromolecules. 143: 704-713.

Shaikh, M., Ali, T.M. and Hasnain, A. (2020). Comparative study on the application of chemically modified corn and pearl millet starches in white sauce. Journal of Food Processing and Preservation. 44(4): 14393.

Shaikh, M.S., Haider, T.M., Ali, A. and Hasnain. (2019). Physical, thermal, mechanical and barrier properties of pearl millet starch films as affected by levels of acetylation and hydroxypropylation. International Journal of Biological Macromolecules. 124: 209-219.

Sharma, M., Singh, A.K. and Yadav, D.N. (2017). Rheological properties of reduced fat ice cream mix containing octenyl succinylated pearl millet starch. Journal of Food Science and Technology. 54(6): 1638-1645.

Singh, V. and Ali, S.Z. (2000). Acid degradation of starch. The effect of acid and starch type. Carbohydrate Polymers. 41(2): 191-195.

Srichuwong, S. and Jane, J.L. (2007). Physicochemical properties of starch affected by molecular composition and structures: A review. Food Science and Biotechnology. 16: 663-674.

Suma, P.F. and Urooj, A. (2015). Isolation and characterization of starch from pearl millet (*Pennisetum typhoidium*) flours. International Journal of Food Properties. 18(12): 2675-2687.

Wu, Y., Lin, Q., Cui, T. and Xiao, H. (2014). Structural and physical properties of starches isolated from six varieties of millet grown in China. International Journal of Food Properties. 17(10): 2344-2360.

Yanez, G.A. and Walker, C.E. (1986). Effect of tempering parameters on extraction and ash of proso millet flours. Cereal Chemistry. 63(2): 164-167.

Yang, S., Cao, Y.L., Kim, H., Beak, S.E. and Song, K.B. (2018). Utilization of foxtail millet starch film incorporated with clove leaf oil for the packaging of queso blanco cheese as a model food. Starch-Stärke. 70(3-4): 1700171.

Yoo, S.H. and Jane, J.L. (2002). Structural and physical characteristics of waxy and other wheat starches. Carbohydrate Polymers. 49(3): 297-305.

Zeng, F., Ma, F., Kong, Q., Gao, S. and Yu. (2015). Physicochemical properties and digestibility of hydrothermally treated waxy rice starch. Food Chemistry. 172: 92-98.

Zhang, Lu, H.J., Liu, K., Wu, N., Li, Y. and Zhou, K. (2009). Earliest Domestication of Common Millet (*Panicum miliaceum*) in East Asia Extended to 10,000 Years Ago. Proceedings of the National Academy of Sciences of the United States of America. 106: 7367-7372.