Review Article

Millets starch – a potential functional ingredient

Abstract

Millets, small seeded grains from the Chlorideae and Paniceae tribes, have been part of the Indian subcontinent cropping system since 3000 BC. They are categorized as major and minor millets, with major millets including sorghum, pearl, finger, and foxtail, and minor millets like proso, barnyard, little, and kodo. Millets are considered climate smart due to their short cultivation period, less water requirement, and better productivity on marginal lands. They are considered "nutri-cereal" due to their high nutritional value compared to rice, wheat, and corn. Millets are rich in B complex vitamins, lipids, dietary fiber, and polyphenols. Their application depends on the physicochemical, structural, and functional properties of their starch, which is classified as rapidly digestible, slowly digestible, or resistant starch.

1. Introduction

Millets are primitive crops which are the part of Indian subcontinent cropping system since 3000 BC (Pokharia*et al*., 2014). These are small seeded grains belonging to Chlorideae and Paniceae tribes of the Poaceae family. Millets are broadly categorized as major and minor milletsbased on their availability and verity(ICRISAT 2017). Major millets include sorghum, pearl (*Pennisetum glaucum*), finger (*Eleusine coracan*), foxtail (*Seratiaitalica*)while,proso (*Panicum miliaceum*, barnyard (*Echinochloacolane*), little (*Panicum miliare*), and kodo (*Paspalum scrobiculatum*) are classified as minormillets. They are regarded as climate smart crops due to their short cultivation period, less water requirement, high adaptability towards adverse climatic conditions, and better productivity on the marginal lands than the major cereal crops (Bandyopadhyay *et al*., 2017).

Millets are considered as “Nutri-cereal” because of their high nutritional and nutraceutical value compared to rice, wheat and corn (Government of India, 2018). Millets contain 60–70% carbohydrates, 1.5–5% fat, 6–19% protein, 12–20% dietary fiber, and 2–4% minerals. Moreover, millets are rich source of B complex vitamins, lipids, dietary fiber and polyphenols (Ambati & Sucharitha, 2019). The high worldwide demand and acceptance of millets is owing to its gluten free property which makes millets suitable for consumption by people suffering from celiac disease. Additionally, epidemiological studies provide evidences of health promoting and metabolic effects of millet consumption(Anitha *et al*., 2021). Starch is the most abundant storage polysaccharide in plants and is the major component of diet.More than half of total energy supply to human body is contributed by starch rich grains. In case of millets, starch majorly (more than half)contributesto total nutritional constituents of grains. The application of millets for foods and other purposes significantly depends upon the physicochemical, structural, and functional properties of their starch (Mahajan *et al*., 2021). The starch is classified as rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) based on the action of amylases on them and time taken for digestion in the small intestine. The RDS and SDS fraction is hydrolysed to glucose in small intestine, while, the RS fraction is resistant towards enzymatic hydrolysis in stomach and small intestine and fermented by large intestine microbiome (Meenu & Xu, 2019). So resistant starch may also be considered as source of dietary fiber.

2. Millet Starches – composition &isolation

The average starch content of pearl, finger, foxtail, proso, barnyard, little, kodo millets ranges from 55-65%, 53-68%, 57-73%, 58-78%, 48-60%, 43-58%, 46-61% respectively (Kaimal *et al*., 2021). In addition to differences in the starch content amylose contentalso varies in different millets ranging from 13-18% in pearl and finger millets and 1.38-12.35%, 2.24-38.67, 8.90-18.5, 11.9-18%, 15-18% in foxtail, proso, barnyard, little, and kodo millet respectively(Prasad & Sahu, 2023). Furthermore, the average content of resistant starch also differs as 1.89-2%, 9-17%, 35-51%, 8-19%, 40-45%, 45-47%, 37-52% in finger, pearl, foxtail, proso, barnyard, little, and kodo millet respectively (Bora *et al*., 2019). Studies have reported average glycaemic index of major and minor millets as 49-54, 41-54 respectively, whereas that of wheat and rice were observed as 64 and 83 respectively (Sharma & Gujral, 2020)

In the matrix of millet grain, the starch molecule has been found closely enclosed with the protein granules. Different chemical and enzymatic methods are employed to solubilize the protein fraction and obtain starch molecules from the millet grain matrix (Verma *et al*., 2018; Halal *et al*., 2019). The extraction of starch encompasses three successive steps i.e. fragmentation of starch granules, breakage of starch followed by purification of starch. The starches are extracted by wet milling method. In wet milling the millet grain flour is steeped into different mediums viz. neutral (aqueous), acidic, and alkaline followed by steeping in antimicrobial salt solution. The steeping facilitates fragmentation and isolation of starch from the grain flour. After steeping the isolated starch is washed followed by centrifugation to remove undissolved impurities. The sediment layer obtained after centrifugation is collectedanddried (air drying/freeze drying) to obtain native starch(Kanagaraj*et al*., 2019). In case of resistant starch, RS_1 and RS_2 fractions are inherent to the millet grain (Kaimal *et al*., 2021). Whereas, the commercial RS_3 and RS_4 content of resistant starch can be prepared by modification through thermal, chemical, and bio-chemicalmethods, microwave and ultrasonic techniques and combination methods (Zheng *et al*., 2020).

3. Millet Starches – therapeutic role

The millet starches can be used as prebiotic food for the growth of healthy microflora in human gut. Preparation of fermented or germinated foods or addition of cultures of Lactobacillus *plantarum,* Lactobacillus*fermentum,* and Lactobacillus acidophilus as starter culture duringfermentation improve nutrient bioavailability and starch functionality (Kaur *et al*., 2023). Moreover, consumption of millet prebiotics stimulates the immune system and reduces hypercholesterolemia. Moreover, studies have shown the anti- glycaemic response of millet-based food (Bunkar *et al*., 2021) which makes millets a functional food in the management of type-2 diabetes Moreover, studies have also shown the effect of millet consumption against cardiovascular diseases, colon cancer, and celiac disease (Bhat *et al*., 2018). Interestingly millet polyphenols exert a positive effect on resistant starch of millets which enhances the inhibitory effect of millets against metabolic enzymes like amylases and glucosidases and health promoting effect of millet resistant starch (Annor *et al*., 2017). Additionally, the synergistic effect of millet nutritional constituents like starch digestibility have been elucidated. The interaction of millet starch with protein, lipid, and polyphenols through complexing affect millet starch digestibility by reducing its gelatinization and permeability towards digestive enzymes (Zheng*et al*., 2020).

4. Millet starches – application

Millet starch is used either in its native or modified forms in the food and non-food industry. Generally, native and modified starches are used as a binder, thickeners in baked food items, meat products, snack seasonings, as a fat replacer in ice creams, flavor encapsulating agents, emulsion stabilizers in juices, beverages, gelling agents in gums, and gels, foam stabilizer in marshmallows, and as crisping agent for the fried snack products, drug deliver as nano particles, edible films (Sandhu *et al*., 2019). The pearl millet native and chemically modified starch has been reportedly used as fat replacer and to reduce syneresis in white sauce (Sharma *et al*., 2017). Furthermore, the modification of millets starches reduces its gelatinization temperature, improves its solubility, paste viscosity, clarity, and water binding capacity which presents them as an appropriate thickening and stabilizing ingredient in gravies, sauces, and ketchups. Modified starches are also used as texture enhancers in ice creams. The starches reduce the viscosity of aqueous phase of ice-cream thus, reducing the formation of ice crystals. The chemically modified pearl millet starch has been found as an effective fat replacer in cold desserts as compared to other replacers like whey protein concentrate, inulin, and corn starch (Sharma *et al*., 2018) in terms of sensory and thawing characteristics. Millet starches which are chemically modified presents a superior material for the development of edible coatings or films. Millet starch based edible films exhibit improved flexibility, transparency, and reduced water vapour permeability. Moreover, blending of millet starches with gums further enhances the film properties which can be utilised for packaging and coating application (Ju & Song, 2019).

The emerging demand of fiber rich gluten free products among consumers also bringing attention towards the use of millet resistant starch in food products in place of dietary fibers. The higher incorporation of dietary fiber in order to enhance the nutritional content of food product compromises with its sensorial and texture acceptability. Millets RS are significant replacement of wheat for development pf gluten free bakery products like breads, biscuits, cookies, pancakes, and waffles (Onyango*et al*., 2020).

Conclusion

Millets are grown in the arid and semi-arid regions and their better adaptability to environmental stress conditions makes them a superior choice for sustainable cropping system. Millets offers various health promoting and therapeutic advantages. Due to cost effective nature of millet cropping they ensure potential supply of starch at low prices. Starch is a major component of milletgrains,but it is neglected for its utilization as raw material to producecommercial grade starch. The native starch is extracted from millets, however, due to low solubility, poor sheer stability, and high degree of retrogradation native starches are modified by various methods. The modified starch has significant changes in the structural and digestibility characteristics. The native and modified millets starches have potential scope of utilisation in food and non-food applications like development of edible coatings and pharmaceutical industry. Furthermore, the challenges and limitations in millet processing can be addressed to enhance promising utilization of millet starch for industrial applications.

References

Ambati, K., & Sucharitha, K. V. (2019). Millets-review on nutritional profiles and health benefits. *International Journal of Recent Scientific Research*, *10*(7), 33943-33948.

Anitha, S., Kane-Potaka, J., Tsusaka, T. W., Botha, R., Rajendran, A., Givens, D. I., & Bhandari, R. K. (2021). A systematic review and meta-analysis of the potential of millets for managing and reducing the risk of developing diabetes mellitus. *Frontiers in nutrition*, 386.

Bandyopadhyay, T., Muthamilarasan, M., & Prasad, M. (2017). Millets for next generation climate-smart agriculture. *Frontiers in plant science*, *8*, 1266.

Bhat, S., Nandini, C., &Tippeswamy, V. (2018). Significance of small millets in nutrition and health-A review. *Asian Journal of Dairy and Food Research*, *37*(1), 35-40.

Bunkar, D. S., Goyal, S. K., Meena, K. K., &Kamalvanshi, V. (2021). Nutritional, functional role of kodo millet and its processing: a review. *International Journal of Current Microbiology and Applied Sciences*, *10*(01), 1972-1985.

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

ICRISAT (2017) A short history of millets and how we are recognising their importance in the modern context. https://www.icrisat.org/a-short-history-of-millets-and-how-we-are-recognising-their-importance-in-the-modern-context/

Ju, A., & Song, K. B. (2019). Development of teff starch films containing camu-camu (Myrciariadubia Mc. Vaugh) extract as an antioxidant packaging material. *Industrial Crops and Products*, *141*, 111737.

Kaimal, A. M., Mujumdar, A. S., & Thorat, B. N. (2021). Resistant starch from millets: Recent developments and applications in food industries. *Trends in Food Science & Technology*, *111*, 563-580.

Kanagaraj, S. P., Ponnambalam, D., & Antony, U. (2019). Effect of dry heat treatment on the development of resistant starch in rice (Oryza sativa) and barnyard millet (Echinochloafurmantacea). *Journal of Food Processing and Preservation*, *43*(7), e13965.

Kaur, B., Singh, A., Suri, S., Usman, M., & Dutta, D. (2023). Minor millets: a review on nutritional composition, starch extraction/modification, product formulation, and health benefits. *Journal of the Science of Food and Agriculture*.

Mahajan, P., Bera, M. B., Panesar, P. S., & Chauhan, A. (2021). Millet starch: A review. *International Journal of Biological Macromolecules*, *180*, 61-79.

Meenu, M., & Xu, B. (2019). A critical review on anti-diabetic and anti-obesity effects of dietary resistant starch. *Critical reviews in food science and nutrition*, *59*(18), 3019-3031.

Ministry of Agriculture & Farmers Welfare, Government of India, International year of Millets (2018). http://www.nutricereals.dac.gov.in

Onyango, C., Luvitaa, S. K., Unbehend, G., & Haase, N. (2020). Physico-chemical properties of flour, dough and bread from wheat and hydrothermally-treated finger millet. *Journal of Cereal Science*, *93*, 102954.

Pokharia, A. K., Kharakwal, J. S., & Srivastava, A. (2014). Archaeobotanical evidence of millets in the Indian subcontinent with some observations on their role in the Indus civilization. *Journal of Archaeological Science*, *42*, 442-455.

Pragyani, B., Sanaa, R., & Massimo, M. (2019). Characterisation of several types of millets as functional food ingredients, Intern. *Journal of Food Sciences. and Nutrition*, *70*(6), 714-724.

Prasad, P., & Sahu, J. K. (2023). Effect of soaking and germination on grain matrix and glycaemic potential: A comparative study on white quinoa, proso and foxtail millet flours. *Food Bioscience*, *56*, 103105.

Sandhu, K. S., Sharma, L., Kaur, M., & 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.

Sharma, B., & Gujral, H. S. (2020). Modifying the dough mixing behavior, protein & starch digestibility and antinutritional profile of minor millets by sprouting. *International Journal of biological macromolecules*, *153*, 962-970.

Sharma, M., Singh, A. K., & 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*, 1638-1645.

Sharma, M., Yadav, D. N., Singh, A. K., Vishwakarma, R. K., &Sabikhi, L. (2018). Impact of octenyl succinylated pearl millet (Pennisetum typhoides) starch addition as fat replacer on the rheological, textural and sensory characteristics of reduced-fat yoghurt. *International Journal of Dairy Technology*, *71*(3), 723-733.

Verma, V. C., Kumar, A., Zaidi, M. G. H., Verma, A. K., Jaiswal, J. P., Singh, D. K., & Agrawal, S. (2018). Starch isolation from different cereals with variable amylose/amylopectin ratio and its morphological study using SEM and FT-IR. *Int. J. Curr. Microbiol. App. Sci*, *7*(10), 211-228.

Zheng, M. Z., Xiao, Y., Yang, S., Liu, H. M., Liu, M. H., Yaqoob, S.,& Liu, J. S. (2020). Effects of heat–moisture, autoclaving, and microwave treatments on physicochemical properties of proso millet starch. *Food science & nutrition*, *8*(2), 735-743.