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READY-TO-RECONSTITUTE AND INSTANT MIX MILLET PRODUCTS: A COMPREHENSIVE REVIEW OF BIOCHEMICAL, PROCESSING TECHNIQUES AND SENSORY ATTRIBUTES

Ravina Parmar[1]*, Neeraj Seth[1], Rajdeep Gandhi[1], Renuka Rathod[1], V.S. Vyas[1], Neha Bharti[1] and B.M. Khanpara[2]

[1]Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra, Gujarat, India
[2]Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India
*Corresponding author E-mail : riyuparmar21@gmail.com

ABSTRACT

Millets, ancient grains renowned for their nutritional richness and adaptability to diverse growing conditions, are experiencing renewed interest as a sustainable food source. The review study explores the development of millet-based ready-to-reconstitute (RTR) and instant mix food products, emphasizing their nutritional benefits, processing techniques, and consumer acceptance. Catering to health-conscious consumers, these products offer nutrient-rich, easy-to-prepare options that require only the addition of water. Naturally gluten-free and with a low glycemic index, RTR products are particularly suitable for individuals with gluten intolerance and diabetes. Processing methods are designed to preserve the nutritional integrity of millets while ensuring convenience and sensory appeal. Nutritional analysis highlights their potential as a valuable addition to the modern diet and sensory evaluations demonstrate high consumer acceptance, particularly for products that balance traditional flavours with contemporary convenience. Future research should focus on enhancing shelf life, exploring diverse formulations, and expanding consumer awareness to fully realize the potential of these products in the global market. Overall, the development of RTR millet-based products presents a significant opportunity to improve global food security and nutrition by integrating millets into the diets of a broader population and promoting their adoption as a staple food.

Key words : Ready-to-reconstitute, Instant mix, Millet products, Gluten-free, Sensory attributes, Processing Techniques.

Introduction

The consumer's rapidly changing lifestyle necessitates convenience in terms of time and energy savings. Because of rising urbanization and development, the market for processed goods in developing nations such as India has increased. Due to this change in the market, consumer behavior has changed, especially for women who are more likely to work full-time, eat out, and be influenced by the media. Consequently, there has been a notable increase in the market demand for foods that are ready to eat (RTE) and ready to cook (RTC). The ready-to-eat (RTE) and ready-to-cook (RTC) food industry in India was estimated to be worth $557.6 million in 2021. From 2022 to 2031, it is expected to grow at a compound annual growth rate (CAGR) of 17.6%, reaching $2,861.3 million (Anonymous, 2022).

Ready to reconstitute or Instant meals are a fantastic convenience in the fast-paced society of today (Negi *et al*., 2021), reducing the amount of time spent cooking while also providing the extra benefit of a long shelf life and simplicity of transport. There is a lot of interest in the development of ready-to-reconstitute (RTR) meals because of the growing demand for convenient and healthful food items worldwide. This food category

includes processed and dehydrated or partially dehydrated foods that may be stored without refrigeration for lengthy periods of time. In order to rehydrate or reconstitute these meals to their original or preferred texture and consistency with light heating or warming, users merely need to add a certain volume of liquid (Budnimath *et al*., 2023).

Before being consumed, dry, ready-to-reconstitute meals must be combined with water. The easiest foods are instant mixes, which need to be reconstituted in boiling water and simmered for two to ten minutes, depending on the food's content and processing method (Patel *et al*., 2022). In today's society, when individuals seek convenience in the kitchen to meet time constraints, instant foods are a must for every home. Instant food items take up a significant amount of shelf space in supermarkets and super markets within the processed food category (Wadikar *et al*., 2016).

Once considered the main food of the poor, millets are gradually evolving into something 'trendy' and 'cool'. Modern consumers are gradually but steadily seeing nutrient-rich millets as a viable substitute for wheat and rice due to rising worries about lifestyle illnesses and the 'refined' eating culture (Shah *et al*., 2024). The main component of traditional diets in Africa and Asia include adult meals, beverages, and weaning foods like porridge, bread and snacks, all of which are effectively made from millet grains (Pei *et al*., 2022).

Millets are known to be nutrient-dense foods (Tiwari *et al*., 2023), providing vital nutrients and significant bioactive chemicals that lower the risk of illness and promote improved health (Biradar *et al*., 2024). Flavonoids, carotenoids, phenolic acids, lignin, beta-glucan, dietary fiber, and saponins are among their most abundant components (Sunil *et al*., 2024). Furthermore, these grains are high in micronutrients such as calcium, iron, zinc, and vitamin B, which includes thiamine, niacin, and riboflavin (Malathi *et al*., 2024). Millets serve as a protective factor against a number of serious diseases. Millets reduce the risk of cardiovascular disease and gastrointestinal disorders like ulcers or colon cancer, protect against type 2 diabetes, increase energy, slow the onset of cancer, improve the muscular and neural systems, help manage respiratory conditions like asthma, aid in body detoxification, effectively lower blood pressure, optimize kidney and liver function, fortify the immune system, relieve gas, constipation, and bloating, and are a powerful source of prebiotics (Chandrasekara and Sahidi, 2011; Devrajj and Chikkanna, 2024).

The major goal of this research is to investigate and assess the potential of millet-based RTR food items in satisfying the increasing customer demand for convenient, nutritious and health-promoting food alternatives. In order to meet the fast-paced needs of contemporary customers, this study will concentrate on the creation, processing, and sensory assessment of RTR millet-based goods. Furthermore, the study will investigate how different processing methods, including roasting, drying, and soaking, affect the goods' overall consumer acceptance, rehydration capabilities, and nutritional value. By analysing the reconstitution ratios and sensory attributes, this study aims to contribute to the growing body of knowledge on the use of millets in convenient food products and to support the increasing trend of incorporating traditional grains into modern diets for better health outcomes.

Ready-to-reconstitute Food Products

Ready-to-reconstitute or instant meals benefit consumers by saving time cooking, providing a consistent good flavour, producing a healthy product, and having a long shelf life. When compared to regularly prepared food products, instant foods not only make preparation easier, but they also have the added benefit of being easier to store and carry because they weigh less (Negi *et al*., 2021). Foods that are ready to reconstitute only need to be boiled for 5-7 minutes in order to regain their original consistency, depending on the food's composition and processing method.

Millet Based Instant Traditional and Dessert Mixes : The focus of millet-based instant traditional and dessert mixes is on traditional cuisine and desserts, appealing to people seeking simple, comfortable, and frequently sweet, culturally relevant recipes. These products offer a convenient way to enjoy the wholesome goodness of millet, a nutritious ancient grain, in a variety of traditional recipes and desserts (More *et al*., 2024). These blends are expertly designed to maintain the genuine flavours of traditional recipes while offering a simple and quick way to prepare them. Ideal for busy lifestyles, they allow you to enjoy comforting, culturally rich meals in minutes, without compromising on taste or nutrition. Perfect for those who appreciate the balance of tradition and modern convenience.

Millet Instant Dried Mix : The instant meal mix often comprises pre-cooked and dried millet grains, which are commonly blended with other ingredients such as spices, seasonings, legumes, or vegetables. Such a mix's objective is to offer a quick and simple dinner choice that may be made by only adding hot water or briefly cooking. Due to their nutritional advantages, millet instant dry mixes are becoming more widely available in health-conscious markets and are popular in areas where millet is a staple

diet (Sunil *et al*., 2024).

Instant Millet-based Meal Mixes : Instant Millet-Based Meal Mixes refers to pre-prepared, convenient food products made from millet that can be quickly and easily cooked or reconstituted. These mixes are designed for ease of use and typically require minimal preparation time. They can include various types of meals or dishes that are traditionally made from millet, such as khichdi or pulav (Dadhwal and Nagpal, 2024).

RTR Smoothie Mix : An RTR Millet Smoothie Mix is a specific type of ready-to-reconstitute smoothie mix that includes millet as one of the key ingredients. It is a convenient product designed to help users quickly prepare a smoothie by simply adding liquid, such as water, milk, or juice. Millets are highly nutritious, gluten-free grains that add fibre, vitamins, minerals and a slight nutty flavour to the smoothie. This mix is designed to provide a quick and easy way to prepare a nutritious smoothie by simply adding liquid and blending (Neeharika and Suneetha, 2024).

Processing Techniques

Processing millet-based instant mixes involves several critical steps, each contributing to the final product's quality and nutritional value. These steps typically include cleaning, soaking, autoclaving, drying, and mixing, as illustrated in the flowcharts (Figs. 1 to 4). The cleaning and soaking stages are essential for removing impurities and preparing the grains for subsequent processing. Autoclaving ensures microbiological safety, while drying processes are crucial for achieving the desired moisture content and extending shelf life (Yadav *et al*., 2011; Bunkar *et al*., 2020).

Processing techniques vary depending on the type of millet and the specific product. Traditional methods, including sun drying and manual crushing, are commonly used for processing. Techniques such as autoclaving and vacuum packaging provide more controlled approaches to ensure product quality and preservation (Tulasi *et al*., 2020). Traditional methods are typically simpler and more accessible but may compromise food safety and quality. In contrast, advanced techniques often provide better control over processing conditions, leading to improved product safety, shelf life, and overall quality. Innovations include the use of stevia and skim milk powder, reflecting trends towards healthier ingredients and enhanced flavour profiles (Negi *et al*., 2021). Fig. 3 illustrates these variations in the context of different millet-based instant mixes.

The choice of processing techniques significantly affects the quality of millet-based instant mixes. For

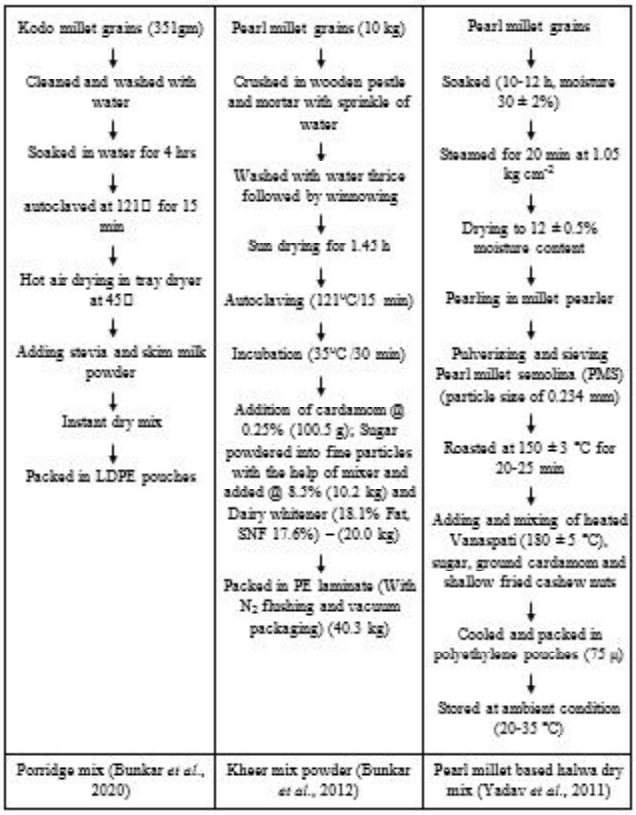

Fig. 1 : Flowchart of processing steps for millet-based instant traditional and dessert mixes.

instance, autoclaving and hot air drying are critical for ensuring microbiological safety and extending shelf life (Bunkar *et al*., 2020). These processes also influence the nutritional profile, including moisture content, fibre retention, and antioxidant levels. Properly executed processing ensures that the final product retains its nutritional benefits while achieving desirable sensory attributes such as texture and flavour (Yadav *et al*., 2011; Negi *et al*., 2021).

Processing millet-based instant mixes presents several challenges. Scalability of traditional methods can be problematic, as shown in flowchart, where manual techniques are used (Tulasi *et al*., 2020). Consistency in product quality is another challenge, particularly when varying processing conditions are employed. Cost considerations and the need for specialized equipment, such as that required for advanced drying methods, can also influence the choice of processing techniques (Negi *et al*., 2021).

Reconstitution / rehydration ratio

The reconstitution ratio refers to the amount of liquid required to restore a dried or concentrated food product to its original or intended consistency. This ratio is crucial when dealing with powdered or dehydrated foods, as it helps determine the correct volume of liquid needed for

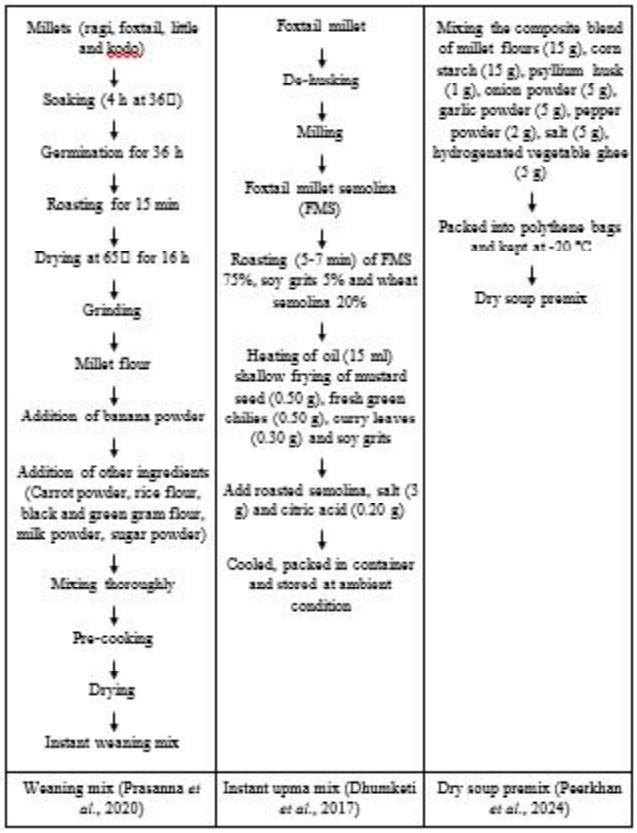

Fig. 2 : Process flowchart for millet-based instant dried mixes.

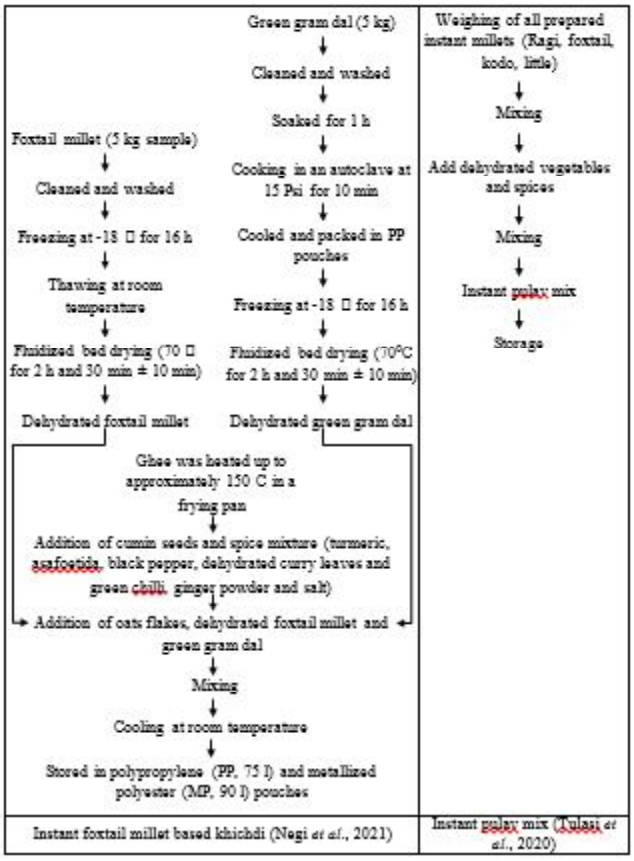

Fig. 3 : Process flowchart for millet-based instant meal mixes.

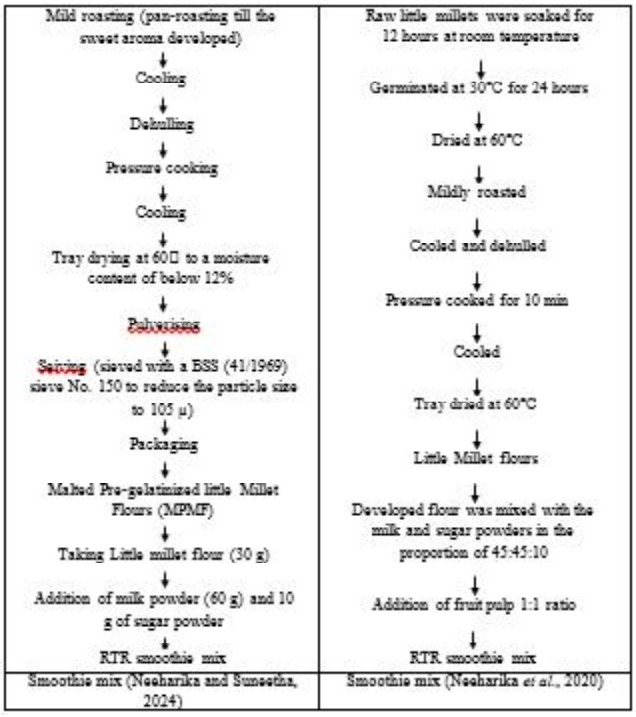

Fig. 4 : Process flowchart for millet-based RTR smoothie mixes.

proper rehydration. It is calculated as the ratio between the mass of the rehydrated product and the initial mass of the dried food sample (Nayi *et al*., 2023; Akther *et al*., 2020). Rehydration ratio (RR) of the dehydrated product can be calculated by using following equation:

$$RR = \frac{\text{Mass of sample after rehydration (g)}}{\text{Mass of sample before rehydration (g)}} \quad (1)$$

The rehydration ratio of food products is strongly influenced by the water absorption capacity of their various components, such as proteins, fibers, and starches. These elements differ in their ability to absorb water, leading to variations in the rehydration ratio. For example, foods high in protein or fiber, like millet, tend to absorb more water, resulting in a higher rehydration ratio. The temperature of the water used for rehydration also significantly affects the process. Hot water typically enhances both the rate and extent of water absorption by expanding the food's cellular structure, allowing more water to penetrate rapidly (Nayi *et al*., 2023; Nadaf *et al*., 2021). In contrast, rehydrating with cold or lukewarm water can slow the process and may result in incomplete rehydration, potentially affecting the texture and necessitating a higher rehydration ratio to achieve the desired consistency.

Reconstitution methods for various millet products highlight the importance of specific ratios and techniques. For instance, approximately 35 g from a pouch of packed kodo millet porridge mix (KMPM) was combined with water in a 1:5 ratio (dry mix: water), with the water

temperature maintained at 90°C for 10 minutes or until the desired consistency was achieved (Bunkar *et al*., 2020). In the case of instant foxtail millet khichdi (FMKM), reconstitution was accomplished within 4 minutes using a ratio of 1:1.8 (instant mix: water) (Negi *et al*., 2021). Reconstituting pearl millet kheer mix (PMKM) involved boiling water and adding approximately 67 g of the mix in a 1:5 ratio (dry mix: water), with the water temperature kept at 90°C for 5 minutes or until the desired consistency was obtained. Ratios of 1:2, 1:3 and 1:4 produced a product with an unsatisfactory texture, while the 1:6 ratio resulted in an overly thick and viscous product (Bunkar *et al*., 2012). For ready-to-reconstitute little millet-based smoothie mixes (RTRSM), the dry mix was combined with 1.5 times the water and stirred thoroughly to achieve the desired smoothie consistency (Neeharika *et al*., 2020; Neeharika and Suneetha, 2024). Similarly, for millet soup reconstitution, about 10 g of the premix was added to 100 mL of water with continuous stirring (Peerkhan *et al*., 2024).

Fig. 5 represents the variation in the rehydration ratio of different instant mixes. The rehydration ratio (RR) of the Pearl Millet-Based Halwa Dry Mix (PMHM) was found to be 1.95 (Yadav *et al*., 2011). In comparison, a higher RR value of 3.5 was reported for the foxtail millet semolina-based upma mix (FMSU). The increased RR in the FMSU suggests that it can absorb more water compared to the control sample. This enhancement in RR with a greater amount of water may be attributed to the increased water availability and the extended time allowed for reconstitution to achieve the desired consistency (Dhumketi *et al*., 2017).

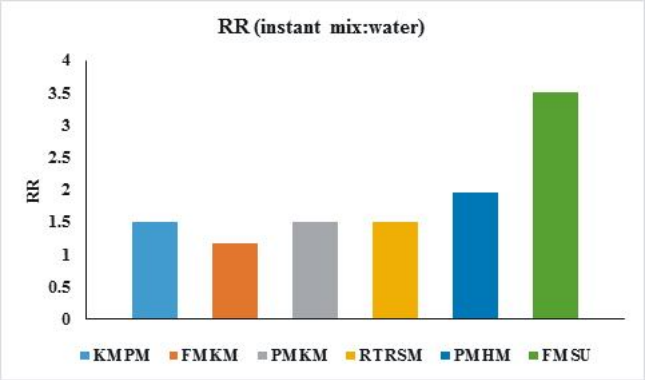

Fig. 5 : Variation in rehydration ratio of different instant mix.

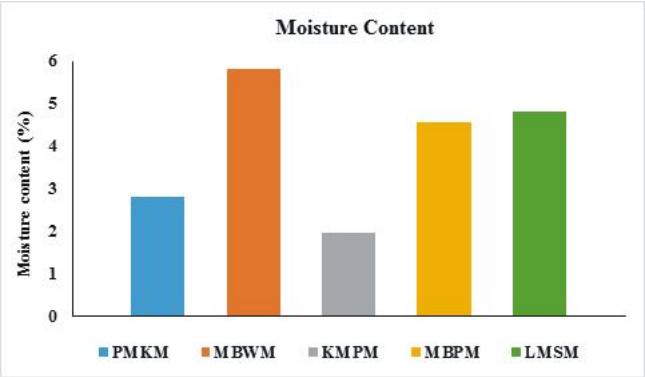

Fig. 6 : Variation in moisture content.

Biochemical parameters

Moisture Content : The variation in moisture content can be attributed to differences in drying methods, ingredient composition, and hygroscopic properties of the millets. Fig. 6 shows the variation in moisture content across different millet-based instant mixes. The moisture content for the various millet-based mixes was 2.80% for the pearl millet-based kheer mix (PMKM), 5.81% for the millet-based weaning mix (MBWM), 1.96% for the kodo millet-based porridge mix (KMPM), 4.55% for the millet-based pulav mix (MBPM), and 4.81% for the little millet smoothie mix (LMSM) (Bunkar *et al*., 2012; Bunkar *et al*., 2020; Prasanna *et al*., 2020; Neeharika *et al*., 2020; Tulasi *et al*., 2020).

Protein : The protein content of various millet-based mixes was reported as 17.65% for the millet-based instant weaning mix (MBWM) (Prasanna *et al*., 2020), 5.50% for the kodo millet-based porridge mix (KMPM) (Bunkar *et al*., 2020), 8.57% for the millet-based instant pulav mix (MBPM) (Tulasi *et al*., 2020), 12.89% for the little millet smoothie mix (LMSM) (Neeharika and Suneetha, 2024) and 5.84% for the pearl millet kheer mix (PMKM) (Bunkar *et al*., 2012), as shown in Fig. 7. The differences in protein content arise from the type of millet used and the addition of protein-rich ingredients. MBWM has the highest protein due to fortification with soy or dairy proteins for nutritional enhancement in infant diets, while KMPM has lower protein, reflecting the intrinsic composition of kodo millet and minimal fortification.

Fat : The observed variations in fat content reflect the use of specific millets and fat-rich components. Figure 8 illustrates the variation in fat content across different millet-based instant mixes. The fat content of the millet-based instant weaning mix (MBWM) was 4.71% (Prasanna *et al*., 2020), the millet-based pulav mix (MBPM) had 3.60% (Tulasi *et al*., 2020), the little millet smoothie mix (LMSM) contained 7.54% (Neeharika and Suneetha, 2024), the Kodo millet-based porridge mix (KMPM) contained 0.83% (Bunkar *et al*., 2020) and the pearl millet dry kheer mix (PMKM) had 4.38% (Bunkar *et al*., 2012).

Carbohydrate : The carbohydrate content of the millet-based instant weaning mix (MBWM) was 66.62% (Prasanna *et al*., 2020), the millet-based pulav mix

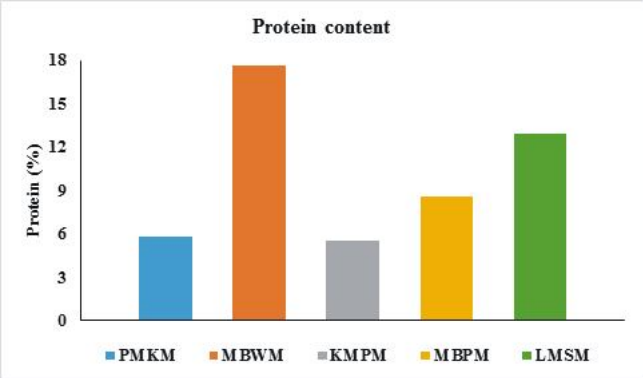

Fig. 7 : Variation in protein content.

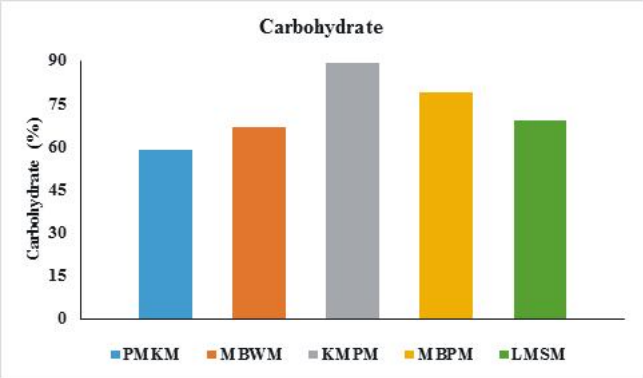

Fig. 9 : Variation in carbohydrate content.

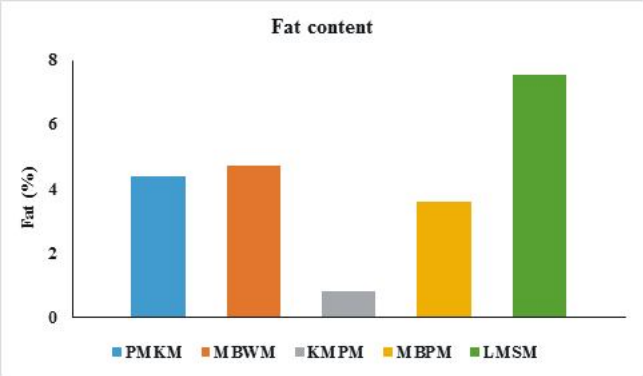

Fig. 8 : Variation in fat content.

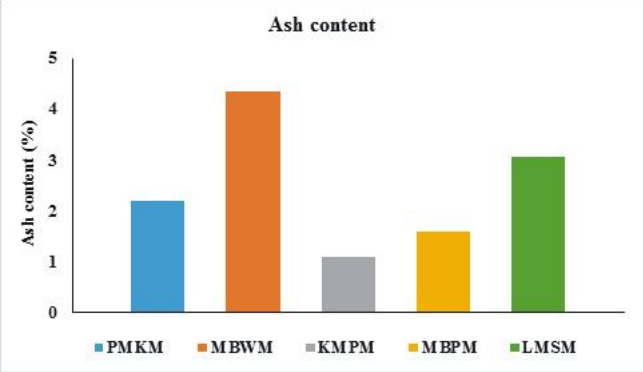

Fig. 10 : Variation in ash content.

(MBPM) had 78.75% (Tulasi *et al*., 2020), the little millet smoothie mix (LMSM) contained 68.96% (Neeharika and Suneetha, 2024), the Kodo millet-based porridge mix (KMPM) had 89% (Bunkar *et al*., 2020), and the pearl millet kheer mix (PMKM) contained 58.8% (Bunkar *et al*., 2012), as presented in Fig. 9. Carbohydrate content variations can be linked to the intrinsic carbohydrate levels of different millets and additional carbohydrate-rich ingredients like sugars in dessert mixes.

Ash content : Ash content reflects the mineral composition of the products. MBWM's higher ash content indicates fortification or natural mineral retention from millets and supplementary ingredients, whereas PMKM's lower ash content corresponds to processing losses or refined ingredient use. Fig. 10 illustrates the variation in ash content among different millet-based instant mixes. The ash content of the millet-based instant weaning mix (MBWM), millet-based pulav mix (MBPM), little millet smoothie mix (LMSM), Kodo millet-based porridge mix (KMPM), and pearl millet kheer mix (PMKM) was 4.34%, 1.58%, 3.05%, 2.2% and 1.1%, respectively (Bunkar *et al*., 2012; Bunkar *et al*., 2020; Prasanna *et al*., 2020; Tulasi *et al*., 2020; Neeharika and Suneetha, 2024).

The analysis of various millet-based instant mixes reveals distinct nutritional profiles. The moisture content ranged from 1.96% to 5.81%, indicating the stability and preservation quality of the mixes. Protein content varied significantly, with the highest being 17.65% in the millet-based weaning mix. Fat content ranged from 0.83% to 7.54%, reflecting differences in formulation. Carbohydrate content was notably high in kodo millet-based porridge mix at 89%, while ash content ranged from 1.1% to 4.34%, showing the mineral content variability. These findings highlight the diverse nutritional benefits and formulation specifics of each millet-based mix.

Sensory Attributes of Millet based Instant Mix

The reconstituted smoothies were assessed for sensory attributes by semi-trained panelists using a 9-point hedonic scale, where 1 indicated "disliked extremely" and 9 indicated "liked extremely" (Dhumketi *et al*., 2017; Neeharika *et al*., 2020; Prasanna *et al*., 2020; Tulasi *et al*., 2020; Neeharika & Suneetha, 2024). Fig. 11 shows the variation in overall acceptability of different instant mixes.

The upma formulation (FMUM), composed of 75% foxtail millet semolina, 20% wheat semolina, and 5% soy grits, received the highest sensory scores across all attributes, including color and appearance (8.42), taste (8.25), flavour (8.63), texture (8.30) and overall acceptability (8.42) (Dhumketi *et al*., 2017). The weaning

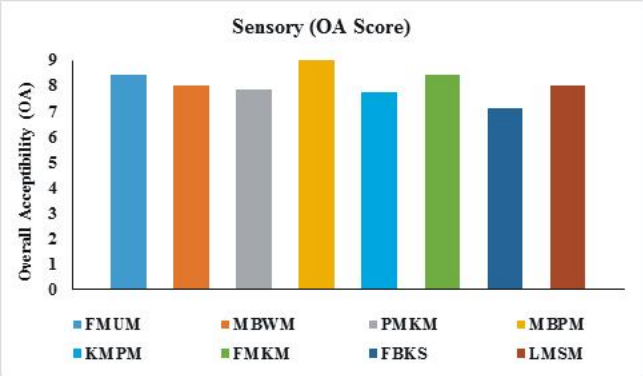

Fig. 11 : Variation in overall acceptability of different instant mixes.

mix (MBWM) was rated for color and appearance (7.33), flavour (7.66), consistency (7.66) and overall acceptability (8) (Prasanna *et al*., 2020). The overall acceptability score for pearl millet-based ready-to-reconstitute kheer (PMKM) was 7.68 (Bunkar *et al*., 2012).

For millet-based pulav mix (MBPM), sensory scores were 8 for colour, flavour, and taste, 9 for appearance, and 9 for overall acceptability (Tulasi *et al*., 2020). The kodo millet-based porridge (KMPM) was evaluated for colour and appearance (6.20), body and texture (7.58), consistency (8.20) and overall acceptability (7.76) (Bunkar *et al*., 2020). The overall acceptability of the Instant Millet Khichdi mix (FMKM) was 8.45 (Negi *et al*., 2021).

Millet soup (foxtail, barnyard and kodo millet) (FBKS) variations had colour scores between 7.12 and 7.66, taste scores from 7.00 to 7.76 and overall acceptability ranging from 7.40 to 8.14, with the optimized sample, achieving an overall acceptability score of 7.12 (Peerkhan *et al*., 2024). The highest scores for appearance, texture, flavour, taste, and overall acceptability of little millet-based smoothies (LMSM) were 8.13, 8.20, 7.27, 8.07, and 8.00, respectively (Neeharika and Suneetha, 2024). The millet based banana smoothie achieved the best overall acceptability score of 8.40 ± 0.51, while the papaya smoothie had the lowest at 8.20 ± 0.41 (Neeharika *et al*., 2020).

Millet-based instant mixes demonstrate strong sensory attributes across a range of products. The upma formulation (FMUM) received the highest sensory ratings for all attributes, reflecting its excellent colour, taste and overall acceptability. The Instant Millet Khichdi mix (FMKM) and millet-based pulav mix (MBPM) also achieved high scores, indicating strong overall appeal. Weaning mix (MBWM) and pearl millet-based kheer (PMKM) showed favourable sensory ratings, while kodo millet-based porridge (KMPM) and millet soups exhibited varied acceptability depending on the specific formulation. Little millet-based smoothies (LMSM) scored well, with banana smoothies being particularly well-received. Overall, these products are well-regarded for their sensory qualities, highlighting the versatility and consumer preference for millet-based instant mixes.

Future scope

The future of millet-based RTR food products looks bright, with numerous prospects for innovation and expansion. Advancements in food processing technology have the potential to improve these items' nutritional profile, shelf life and sensory attributes. Additionally, there is potential for creating novel and varied millet-based RTR products that can satisfy a range of dietary requirements, including as those for vegan, gluten-free, and functional meals. Furthermore, improved consumer awareness and education regarding millets' health advantages may boost demand, promoting additional research and development in this area. Future study into millet-based product processing procedures may focus on optimizing conditions to increase production and quality while lowering environmental effect. Emerging trends include the use of more energy-efficient techniques and the incorporation of novel additives to improve nutritional advantages. The future of millet-based instant mixes is anticipated to be significantly shaped by technological advancements including automated systems and better drying techniques. Collaborations between academia, industry, and policymakers could help in scaling up production and making millet-based RTR products more accessible to a broader audience, thus contributing to global food security and sustainability.

Conclusion

The development and consumption of millet-based ready-to-reconstitute (RTR) food items is a possible solution to the growing need for convenient, nutritious, and health-promoting dietary options. Millets' strong nutrient profile makes them a sustainable and adaptable substitute for traditional grains as the world's population moves toward healthier and quicker meal options. The various processing procedures, like as soaking, roasting, and drying, are critical in improving the nutritional quality, rehydration characteristics, and overall sensory characteristics of these foods. Millet-based RTR products, such as instant mixes and smoothies, not only cater to modern dietary preferences but also help in preserving traditional culinary practices. This review shows the potential of millets in addressing contemporary health concerns while also advocating the revival of these ancient grains in modern diets by investigating their nutritional and sensory properties. Future convenient, health-conscious food offers may be significantly shaped by

millet-based RTR items as the food industry innovates further.

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