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Enhancing cooking, sensory and nutritional quality of finger millet noodles through incorporation of hydrocolloids

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Abstract
In the present study attempts were made to prepare nutrient-rich noodles with blends of finger millet and wheat flour (WH) along various hydrocolloids to improve the cooking quality of noodles. Five types of hydrocolloid blends (4%) were incorporated in finger millet (FM) noodles which included Karaya gum, Gum acacia, Tragacanth, Guar gum and Xanthan gum blending with CMC. Results revealed that the addition of hydrocolloids showed significant improvement in cooking and textural parameters of noodles. Among the hydrocolloids, the higher effect was observed with Karaya gum and CMC blend significantly(p=0.05) resulted in less cooking time and cooking loss when compared to other hydrocolloids and control Finger Millet noodles without hydrocolloids. Results revealed that these noodles were significantly rich in nutrients when compared to wheat noodles.

Keywords: Noodles, cooking quality, hydrocolloids, finger millet

Introduction
Noodles are widely consumed throughout the world, and it is a fast-growing sector because noodles are convenient, low cost, easy to cook and have a relatively long shelf-life [1]. It is one of the essential and staple food in many Asian countries, which is being consumed for thousands of years. Refined wheat flour which is usually used to make noodles are rich in carbohydrates however they lack nutrients like dietary fibre, protein, minerals and vitamins. Given the increasing demand for Nutri dense products for maintaining health and nutrition, there is a requirement to increase the nutritional qualities of noodles to provide health benefits to the consumers. Nutritional profile of noodles can be enhanced by enriching with different fortificants which are potentially rich in dietary fibre, proteins and other nutrients and antioxidants [2]. Several experiments were conducted by many authors to improve the nutritional quality of noodles by addition of chestnut flour [3], malted finger millet flour [1], oyster mushroom [4], potato, corn and bean starches [5], buckwheat flour [6], hull less barley [7].

Finger millet has been perceived as a potential "super cereal" by the United States National Academies is one of the most nutritious among all major cereals [8] It is an important food crop of the poor marginal farmers, especially tribal people of India. It is considerably rich in minerals, and its micronutrient density is higher than that of the world's major cereal grains; rice and wheat. Specifically, it is the most abundant source of calcium among cereals with up to 10-fold higher calcium content than brown rice, wheat or maize and three times than that of milk. It is also rich in iron and fibre, making this crop more nutritive as compared to other most commonly used cereals. Finger millet is rich in essential amino acids like lysine and methionine which are essential in human health and growth but remain absent from most other plant foods. Besides, it also contains useful amounts of the two polyunsaturated fatty acids-linoleic acid and α-linolenic acid metabolised products of which facilitate the healthy development of the central nervous system. It also contains both water-soluble and liposoluble vitamins: thiamin, riboflavin, niacin, and tocopherols [9]. Food hydrocolloids have been exploited for many years in food systems as thickeners, gelling agents, stabiliser, bulking agents and emulsifiers [10].

Hydrocolloids are widely used as functional ingredients in the food industries. Starches and gums (hydrocolloids) are often used together in food systems to provide proper texture, control moisture, and water mobility, improve overall product quality and stability, reduce cost, and/or facilitate processing [11].

In addition to the apparent benefits of taste, texture, mouthfeel, moisture control and water mobility, hydrocolloids can also improve the overall quality and stability of the product [12]. The most significant features of hydrocolloids are their ability to control the rheological properties and texture of food [13]. Food hydrocolloids consist of a vast and diverse number of ingredients sourced from algae, bacteria, fruit and plant extracts [10]. Syed *et al*. [3] studied the effect of hydrocolloids on the quality evaluation of flour based noodles from horse chestnut and reported that addition of 3% guar gum and xanthan gum significantly increased cooking properties and the firmness of cooked noodles. Padalino *et al*. [14] reported that the addition of 2% CMC and gellan gum improved cooking quality and textural properties of spaghetti. [15] reported that the addition of CMC improved the overall acceptability of non-wheat pasta.

Previously several attempts were made by authors to prepare *rag*i noodles, [16]; however, the addition of *ragi* flour was limited to 30% based on sensory attributes. Dissanayake and Jayawardena [17] developed a method for preparing 50% and 100% finger millet (FM) *noodles* and reported that noodles recovery was low, and breakage was high when compared to control rice. Therefore, in the present study, we aimed to improve the nutritional quality of noodles by addition of 50% FM without affecting the sensory, cooking and textural characteristics of FM noodles by addition of suitable hydrocolloids.

Material and Methods

Procurement of Raw Material: Finger millet grain was procured directly from farmers. Refined wheat flour was procured from the local market. Guar gum, Karaya gum and Gum Acacia were procured form Nutriroma, Hyderabad. Xanthan gum was procured from Tapadia Marketing Services, Hyderabad. Gum Tragacanth was procured from Ranchhoddas Odhavji Gaglani & Sons, Mumbai. CMC was procured from SR CARBOCHEM, Hyderabad.

Product formulations

Control – 100(WH)
Control (FM) – 50 (WH): 50 (FM)
FK- 46 (WH): 50 (FM): 2 (Karaya gum): 2(CMC)
FA- 46 (WH)): 50 (FM): 2 (Gum acacia): 2(CMC)
FX- 46 (WH): 50 (FM): 2 (Xanthan gum): 2(CMC)
FT- 46 (WH): 50 (FM): 2 (Tragacanth gum): 2(CMC)
FG- 46 (WH): 50 (FM): 2 (Guar gum): 2(CMC)
* FM- Finger millet, WH- wheat flour, CMC- Carboxy methyl cellulose

Precreation of Noodles

Noodles were prepared in a cold extruder (La Monferrina Pasta making machine, Agaram Industries, Hyderabad). Initially, FM grain was cleaned to remove foreign material, and grain was then milled into flour in a pulveriser (Able manufacturers, Hyderabad). WH and FM flour were weighed and sieved together using BSS 60 sieve to get uniform particle size. Hydrocolloids were mixed with 10ml of water to make into a gel like consistency and added to flour. The mix was conditioned for 15 minutes by adding 250 ml of water (45˚C) to the flour and transferred to the mixing vat of cold extruder and thoroughly mixed for 10 minutes and extruded using noodles die (1.2mm diameter). Noodles were then dried in tray drier (Thermo control systems, Hyderabad) for 7 hours at 60˚C to attain moisture content below 10%.

Cooking quality parameters

Optimum Cooking Time

The optimum cooking time of noodles was evaluated according to Singh *et al*. [18] method. The noodle sample (5 g) was placed in a beaker containing 75 mL distilled water, and one strip was crushed between two glasses in every 30 s. The cooking was continued until white fraction in the central core of crushed noodles was disappeared and the time that passed was recorded as optimum cooking time.

Cooking loss: Cooking loss of noodles was evaluated according to the method of Pakhare *et al*. [19]. The cooking loss was determined by measuring the amount of solid substance lost to the cooking water. 10 g sample of noodles was placed into 100 ml of boiling water in a 500 ml beaker. Cooking water was collected in a pre-weighed glass dish and was placed in a hot air oven at 105°C and evaporated to dryness. The dry residue was weighed and reported as a percentage.

Water uptake

Water uptake of noodles was evaluated according to the method of Özkaya *et al*. [20]. The water uptake was calculated by calculating the difference between the weight of cooked noodles and weight of dried noodles. The cooked noodles were placed on filter paper for 5 min before weighing, to blot the excess adhered water.

Volume increase

The volume increase was evaluated according to the method of Özkaya *et al*. [20]; 25 g noodle was cooked in boiling water (250 mL) on the basis of their optimum cooking time, rested for 5 min and transferred to a beaker filled with 250 mL water. The volume of water overflowed from beaker was recorded. The same procedure was repeated for uncooked noodle as well. The per cent volume increase was calculated on the basis of the difference between the volume of overflowed water for cooked and uncooked noodles.

Sensory evaluation: Sensory evaluation was conducted for the cooked noodle samples.10 member semi-trained panel evaluated the noodles using a 9-point hedonic scale ranging from 1 (extremely disliked) to 9 (extremely liked). The panellists were asked to score for slipperiness, firmness, chewiness, tooth packing, appearance and overall acceptability. The dried noodles were rehydrated in boiling water based on their cooking time and were served hot for the sensory evaluation.

Nutritional analysis

The select samples were estimated for their moisture [21], protein [22], carbohydrate [23], fat [24], ash [25], using standard methods. Total dietary fibre (TDF), soluble dietary fibre (SDF), insoluble dietary fibre (IDF) was determined by enzymatic-gravimetric method [26].

Results and Discussion

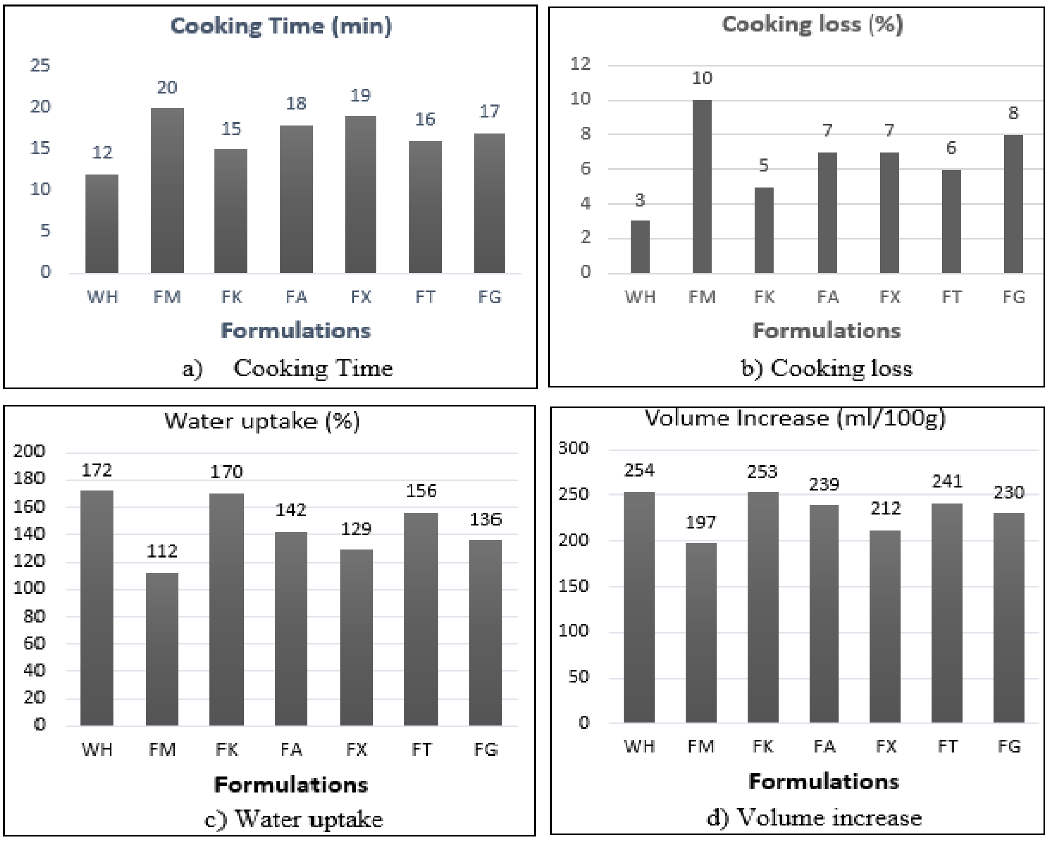
Cooking quality

Cooking quality of noodles is the most critical characteristic for consumers and therefore of great importance to the processing industry. Cooked noodles should have a relatively strong bite with a firm, smooth surface, and good mouthfeel [27]. Cooking quality of noodles is influenced by several factors, such as protein content, ash content, damaged starch,

starch quality, thickness of noodle strands, and frying conditions. Rehydration rate, cooking time, and cooking loss are the measure of cooking quality and ease of preparation. Mean cooking time of RW flour noodles(control) and samples showed significant difference with each other as shown in Figure 1.a. Cooking time of FM noodles without hydrocolloids was found to be highest (20m) while RW noodles recorded the lowest cooking time (15m). Addition of hydrocolloids in general improved the cooking time of FM noodles. Higher effect on cooking time was recorded due to karaya gum in FM noodles, as it reduced the cooking time from 20 min to 15 min followed by gum tragacanth (16 min). The differences in the cooking quality can be attributed primarily to the hydrocolloid fraction that provides as a binder for more retention of water within the noodles. Vijayakumar *et al*. [28] reported that the cooking time of noodles developed from composite flour was higher (15-18 min) when compared to branded noodles (9.3min).

Cooking loss and degree of rehydration ratio are two important factors denoting the cooking quality of noodle. Noodles should have a short cooking time with little loss of solids in the cooking water. Insufficient rehydration usually results in noodle with a hard and coarse texture, but excess water uptake often results in noodle that is too soft and sticky [29]. Cooking losses ranged in between 3% to 10% (Figure 1.b). Highest cooking losses were recorded in FM noodles without hydrocolloids (10%) and lowest in control wheat noodles (3%). This could be due to the reason that millets are gluten free and an addition of FM dilutes gluten and results in poor protein network and thus allow more leaching out of solids from pasta into the cooking water, hence increased the gruel loss [15]. Sudha *et al*. [30] reported that cooking losses were less up to 25% of FM flour incorporation in semolina. Dissanayake and Jayawardena [17] reported that cooking loss was significantly higher in 50%, 100% finger millet noodles when compared to rice noodles. Addition of hydrocolloids significantly reduced cooking losses. FK recorded the lowest cooking losses (5%) followed by FT (6%). This could be due to the fact that gum network formation occurred around starch granules which encapsulate them during cooking and restricting the excessive swelling and diffusion of amylose content [15] and complex formation between amylose and hydrocolloid [31]. Liu *et al*. [32] also reported that hydrocolloid decreased the solubility of starch polymer molecules within the swollen granules.

Per cent rehydration shows the ratio of the weight of cooked noodles to the weight of uncooked noodles [33]. The rehydration ratio affects the cooking qualities and texture of noodles. High-rehydration values gives noodle a soft and sticky texture, while lower rehydration resulted in noodle with coarse and hard texture. That is why optimum rehydration ratio in noodle is required. Water uptake of FM noodles was low when compared with WH noodles (Figure 1.c). Vijayakumar [28] reported similar observations that water uptake decreased significantly when the level of millet flour was increased. Similar observations were reported by Kamini and Saritha [16]. The water uptake of noodles ranged between 129% to 172%. Addition of hydrocolloids significantly increased the water uptake and volume intake of FM noodles (Figure 1.d). It is evident from the results that addition of karaya gum followed by tragacanth gum improved the rehydration ratio of noodles when compared with other hydrocolloids. This might be due to the fact that they are more hydrophilic and have high water binding capacity. Overall the cooking quality studies revealed that FK noodles are relatively closer to WH noodles.

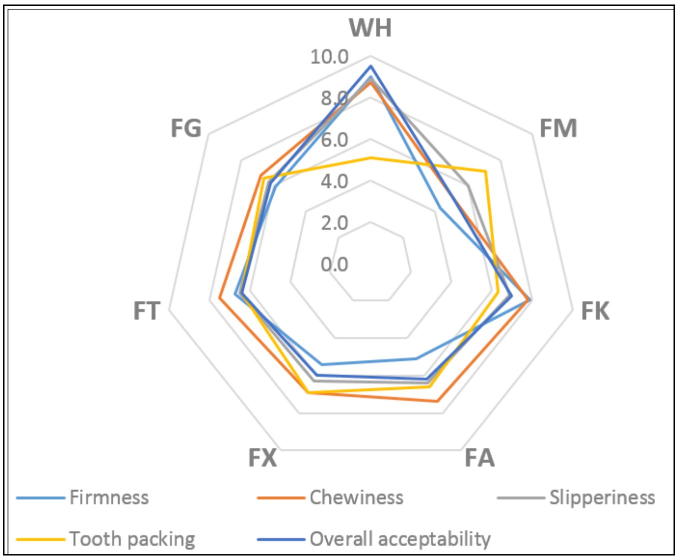


WH- Wheat noodles, FM- Finger millet noodles(without hydrocolloids) FK-Finger millet noodles + Karaya Gum, FA-Finger millet noodles +Gum Acacia, FX-Finger millet noodles + Xanthan Gum, FT- Finger millet noodles+ Tragacanth FG-Finger millet noodles + Guar Gum

Fig 1: Cooking properties of wheat, finger millet noodles (with and without hydrocolloids)

Sensory quality

Sensory properties of raw and cooked noodles are summarised in Figure 2. WH scored highest overall acceptability and FM scored least among all. WH noodles scored highest for transparency, firmness and chewiness. Addition of hydrocolloids significantly improved the sensory scores of finger millet noodles. Slipperiness may be defined as the extent to which the product slides across the tongue. The slippery surface texture is also desirable in noodles [34]. Addition of hydrocolloids significantly improved the slipperiness of noodles when compared to FM noodles. FK had more slippery surface when compared with other noodles. Tooth packing is defined as the amount of starch noodle left on the teeth after masticating one strand of noodle. Thus, a low score is desirable for tooth packing [34]. Control noodles scored lowest for tooth packing whereas finger millet noodles without hydrocolloids scored highest. It can be observed that the addition of hydrocolloids irrespective of type significantly reduced the tooth packing of noodles; however, karaya gum was found to have a higher effect.



WH- Wheat noodles, FM- Finger millet noodles (without hydrocolloids) FK-Finger millet noodles + Karaya Gum, FA-Finger millet noodles +Gum Acacia, FX-Finger millet noodles + Xanthan Gum, FT- Finger millet noodles+ Tragacanth FG-Finger millet noodles + Guar Gum

Fig 2: Sensory evaluation of Wheat vs Finger millet noodles (with and without hydrocolloids)

Nutrient composition

Nutrient composition of noodles is shown in Table 1. It was found that significantly(p=0.05) high amount of fat, ash, TDF, TSF, IDF, calcium and iron contents in FM noodles than in control WH noodles. Protein content was found to be lower in finger millet noodles when compared with control wheat noodles due to its lower protein content. Kamini and saritha [16] reported that the protein content of noodles decreased with increasing finger millet flour in noodles. Calcium content of finger millet flour was found to be significantly higher (196.23 mg) when compared with control noodles (19.58mg) which is ten times higher. Similar results (181.99) were reported by Kamini and saritha [16]. Hadimani *et al.* [35] also reported 162.8 mg/100 g calcium in milled and 454.2 m g/100 g in deglumed finger millet. The iron content of finger millet noodles (4.19) was significantly higher when compared with wheat noodles (1.69).

Table 1: Nutrient content of wheat noodles VS Finger millet noodles (with hydrocolloids) (per 100g)*

Nutrient	WH	FK
Moisture (g)	8.00	9.00
Protein (g)	9.94	8.44
Fat (g)	0.72	1.66
Ash (g)	0.48	1.60
Total Dietary fibre (g)	2.64	10.81
Total Soluble fibre (g)	2.05	9.22
Total Insoluble fibre (g)	0.59	1.57
Carbohydrates (g)	71.29	62.91
Calcium (mg)	19.58	196.23
Iron (mg)	1.69	4.19

WH- Wheat noodles, FK-Finger millet noodles with Karaya Gum * significant p=0.05

Conclusion

The study revealed that the addition of hydrocolloids in the FM noodles positively modified the cooking and textural quality of noodles. Addition of Karaya gum and CMC resulted in significantly higher improvement of cooking and sensory characteristics of noodles. These noodles had higher values of fibre and minerals (calcium and iron) than the control wheat noodles. These noodles can be promoted as a health and functional food suitable for preventing life style diseases.

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