

NUTRITION AND FOOD SCIENCE

Value added products from nutri-cereals: Finger millet (*Eleusine coracana*)

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Abstract

Finger millet also known as ragi in India is one of the important cereals occupies highest area under cultivation among the small millets. Finger millet is comparable to rice with regard to protein (6-8%) and fat (1-2%) and is superior to rice and wheat with respect to mineral and micronutrient contents. It is a major source of dietary carbohydrates for a large section of society. Additionally ragi has enormous health benefits and also a good source of valuable micro-nutrients along with the major food components. In order to develop the value added food products based on ragi, that can able to enrich the nutritional value and also beneficial for good health is the current need for the wellbeing of the society. Food is consumed in combinations. The synergy between foods with other is vital not for taste and delight of eating but also for their high nutritional quality and health benefits. The modern trend for development of new food products aspires for complementary foods in order to fulfill the widening gap of food availability and nutritional security. This paper attempts to discuss the few value added food products incorporating ragi and simultaneously attempts to enlist and document the methodology and techniques in the interest of scientist and common mass.

Key words: Cereal grains, Finger millet, Nutritional properties of millets, Processing and value addition

Introduction

India is the leading producer of small millets namely, finger millet (*ragi*), kodo millet (*kodo*), foxtail millet (*kangni*), barnyard millet (*sawan*), proso millet (*cheema*) and little millet (*kutki*) (Majmdar et al., 2006). Annual planting area under them is around 2.5 million hectares; and nearly 1.5 million hectares is under finger millet comprising about 40-50% of crop's global area. During the last three decades, area under finger millet has declined but with the significant improvement in the productivity (1,500 kg/ha), its annual production is maintained at around 2.4 million tonnes. At present, small millets account for less than 1% of food grains produced in the world (ICAR, 2010). Their cultivation dates back to nearly 5000 years including India. Small millets form an important component of the traditional cropping systems and contribute significantly to the regional food and nutritional security and diversity in the national food basket. They are also important in areas of their production

as dryland crops, as well as for hill agriculture. The small millet grains have longer storage life, and can be termed as famine reserve. The resilience exhibited by them may prove good for their adjustment to different eco-systems and make them potential crops for contingency plantings.

Cereals form a major portion of human diet and are an important source of starch and other dietary carbohydrates (dietary fibre), which play an important role in the energy requirement and nutrient intake of human. The millets are with higher fibre content, and their protein quality and mineral composition contribute significantly to nutritional security of a large section of population residing in the millet growing areas, considered to be the most disadvantaged groups (Desai et al., 2010). Millets are most recognized nutritionally for being a good source of minerals magnesium, manganese and phosphorus. Research has linked magnesium to a reduced risk for heart attack and phosphorus is important for the development of body tissue and energy metabolism. Millets are also rich in phytochemicals, including phytic acid (Shashi et al., 2007), which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk. Thus, millets are strategic in terms of their food, nutritional and livelihood security and their role in local agro-ecosystems

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(Joshi et al., 2008). The finger millet contains important amino acids viz., isoleucine (4.4 g), leucine (9.5 g), methionine (3.1 g) and phenyl alanine (5.2 g) which are deficient in other starchy meals. Millets also contain B vitamins, especially niacin, B6 and folic acid, calcium, iron, potassium, magnesium and zinc (Vachanth et al., 2010).

Finger millet is normally consumed in the form of flour-based foods such as *roti* (unleavened pancake), *mudde* (stiff porridge/dumpling) and *ambli* (thin porridge) and each of these foods have their characteristic features. The detail preparation methods have been reported by (Malleshi et al., 2007).

Finger millet or the *ragi* is usually used for preparation of flour, pudding, porridge and *roti* (Chaturvedi et al., 2008). With the changes in scenario of utilization pattern of processed products and awareness of the consumers about the health benefits, finger millet has gained importance because of its functional components, such as slowly digestible starch and resistant starch (Wadikar et al., 2007).

Traditionally *ragi* is processed either by malting or fermentation (Rao et al., 2001). Malting of finger millet improves its digestibility, sensory and nutritional quality as well as pronounced effect in the lowering of antinutrients. Malting characteristics of finger millet are superior to other millets and rank next to barley malt (Pawar et al., 2007). There are various benefits of malting such as vitamin-C is elaborated, phosphorus availability is increased and lysine and tryptophan are synthesized (Desai et al., 2010). The malted and fermented *ragi* flour are extensively used in preparation of weaning food, instant mixes, beverages and pharmaceutical products (Rao et al., 2001).

Food uses of millets have, however, been confined only to traditional consumers; limited especially to areas of their cultivation, and still have remained underutilized. Processing them using traditional as well as contemporary methods for preparation of value added and convenience products would certainly diversify their food uses. Their exploitation for preparation of ready-to-use or ready-to-cook products would help in increasing the consumption of millets among non-millet consumers and thereby nutritional security. The present paper is an attempt to describe some basic information about finger millet, the processing requirement and some avenue for its value addition and food uses.

Experimental Details

In the present work two basic millets (*kodo* and *ragi*) of Chhattisgarh were considered for study.

Samples of *kodo* and *ragi* were obtained from the local market. Samples were cleaned well before taking any experimental work. Value added products utilizing these grains were prepared keeping in mind the food habits in the niche area as well as broader areas adjoining the production catchments. In order to select the ratios of ingredients, several blends were prepared and processed into targeted foods. The foods were prepared using standard techniques described elsewhere. Sensory evaluation following 9-point hedonic scale for these foods was performed to select the best blending among the lots. To perform sensory evaluation, judges were drawn from the group of faculty and scholars of the university. The judges were trained and given pre-preparation tips for each of the foods and subjective measurement feelings. The blends rated highest among the lot were then selected for the final preparation. In order to determine the nutritional characteristics of these millets, standard methods (Sadasivam et al., 2005) described below were followed.

Moisture content

Moisture content was determined using oven following the method described in AOAC (2007).

Protein

Nitrogen content was determined following the Micro Kjeldhal method described in AOAC (2007) using Gerhardt Digestion and Distillation (model VAP-30), W Germany. Nitrogen was converted into protein by multiplying protein factor 6.25 ($N \times 6.25$). Defatted sample was taken for the estimation.

Total Carbohydrate

Carbohydrate determination was done according to Hedge et al. (1962). It is hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium, glucose is dehydrated to form hydroxy methyl furfural which gives green colour with anthrone reagent (1mg/mL) at 630 nm. Glucose (1×10^{-2} g/mL) is used as standard.

Fat

It is determined by solvent extraction method described in AOAC (2007) through Soxhlet Apparatus using petroleum ether as solvent.

Iron, Magnesium, Calcium

They were determined by AAS method following AOAC (2007).

Phosphorus

Phosphorus is determined by Colorimetric method at 660 nm following the procedure described in AOAC (2007).

Crude fibre

Crude fibre consists mainly of cellulose and lignin (97%) plus some minerals. It can be estimated by treatment of sample first with acid and subsequently with alkali. The loss in weight gives the crude fibre content (AOAC, 2007).

Results and Discussion

Nutritional characteristics

The nutritional characteristics of the two millets are presented in Table 1. Table also gives the comparison of properties of these millets with two major cereals of the world, wheat and rice. From the Table 1, it is clearly seen that the *ragi* millet is nutritionally superior compared to other three crops. *Ragi* millet contains fibre, more mineral and more vitamins, which are normally deficient in Indian diet and has eight times more calcium than other cereals. It is comparable to rice with regard to protein (6-8%) and fat (1-2%) and is superior to rice and wheat with respect to mineral and micronutrient contents. The calcium, phosphorus and iron contents of the millets were analyzed as these three minerals are of nutritional importance in the diets of population who consume millet as staple food. It is a major source of dietary carbohydrates for a large section of society belonging to millet growing areas. In addition to these, millets contain few other micro-nutrient compounds such as lignin, manganese, niacin etc. which are also important for human diet. However, their determination could not be done due to non-availability of the facilities.

Effect of millets on health

Magnesium from millets not only help to reduce the severity of asthma and migraine attacks, but also helps to reduce high blood pressure, diabetic heart disease, atherosclerosis and heart attack. Niacin is been used since ages to reduce high cholesterol levels in the body (Guigliano et al., 2011). Phosphorus from

millets is an important mineral for energy production and is an essential component of Adenosine Triphosphate (ATP) – the energy store of the body (Shashi et al., 2007). It also forms an essential part of nervous system and cell membranes. A cooked cup of millet provides 26.4% daily value for magnesium and 24% daily value for phosphorus. Magnesium from millets also helps to relax blood vessels, enhances nutrient delivery by improving the blood flow and maintains the blood pressure and thus further protects the cardiovascular system. Lignin present in millets is converted to mammalian lignans by the healthy gut micro flora in our body which is thought to protect against breast cancer as well as heart diseases. The insoluble fiber from millets helps in gallstones prevention. A study proved that including insoluble fiber in diet lowers the risk of getting gallstones by 17% compared to women whose diet lack in fiber. This gallstones protection from fiber is dose related, with every 5g increase in insoluble fiber the risk drops by 10%. Millets helps to lower blood glucose levels and improves insulin response (Lakshmi et al., 2002). Finger millet is a humble grain with low glycemic index which makes it more suitable for diabetic patients (Pradhan et al., 2008). They maintain the sugar level of diabetic patient. Additionally, it is a rich source of calcium (344 mg/100g) and helps in supplementing the calcium in human body. Postmenopausal women with signs of cardiovascular disease like high blood pressure, increased cholesterol and obesity can benefit from eating whole grains especially millets by eating them 6 times a week. Whole grains like millet may have health promoting effects equal to or even in higher amount than fruits and vegetables and have a protective effect against insulin resistance, heart diseases, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma and premature death (Cade et al., 2007).

Table 1. Composition of *kodo* and *ragi* millets (per 100 g edible portion, 12% moisture content).

S. No.	Particulars	<i>Kodo</i> millet	<i>Ragi</i> millet	Wheat*	Rice*
1.	Carbohydrate (g)	66.6	72.6	71.2	78.2
2.	Protein (g)	9.8	7.7	11.8	6.8
3.	Fat (g)	1.3	1.5	1.5	0.5
4.	Crude fibre (g)	9.0	3.6	12.9	5.2
5.	Ash (g)	2.6	2.7	1.5	0.6
6.	Calcium (mg)	27	344	41	10
7.	Phosphorus (mg)	188	250	306	160
8.	Iron (mg)	5.0	6.3	3.9	0.5
9.	Manganese (mg)	3.3	3.5	13.3	1.0
10.	Magnesium (mg)	228	130	120	32

* Source : FAO/1970, Rome, Italy, Nutritive value of Indian foods, 1998, NIN, Hyderabad, India

Value addition and value added products

In the foregoing paragraphs, some of the examples of value added products and possibilities of utilizing finger millet as one of the basic ingredients are discussed. Finger millet can be used in a variety of ways and is a great substitute for other grains such as rice and other starchy grains. These products are either in practice or have been demonstrated as avenue for enhanced consumption of finger millet. However, not much scientific studies have been carried out about their preparation and meaningful popularization on large scale.

(i) Multi-grain flour /Composite flour

The concept of multi-grain flour/composite flour is not new to the mankind. Mixing of two-three types of grains or grain and pulses has been in practice since long ago depending upon the availability of such commodities locally or the food habits, but in such cases, the understanding of nutritional security is not necessarily linked. Multi-grain flour by combining wheat and finger millet in the ratio of 7:3 (wheat:finger millet) is one of the simple semi-finished products suitable for making chapatti (roti), as no Indian meal is complete without Indian style bread or roti. In the proposed blend, though the gluten content is reduced significantly the making of chapatti while flattening is not affected. However, the colour of the chapatti turns to slightly dark. Fortification of finger millet in chapattis not only improves the taste but also helpful in controlling glucose levels in diabetic patients very efficiently (Kang et al., 2008). The bulkiness of the fibres and the slower digestion rate makes us feel fuller on, fewer calories and therefore may help to prevent from eating excess calories. Its high fiber content is further helpful to the individuals having the problem of constipation (Cade et al., 2007).

(ii) Papad

Addition of finger millet as one of basic ingredient to the tune of 15-20% (w/w) along with other essential ingredients such as black or green gram, rice and spices has become a tradition in millet growing areas of South India. According to a report, addition of finger millet up to 60% in papad is possible and practiced in some parts of Karnataka (Begum et al., 2007).

Papad from finger millet flour is also prepared in which it is used as base material mixed with spices and salt. Flour is first cooked in water till it is gelatinized and dough is prepared. Thin sheet from the dough is prepared by rolling it and cutting into desired shapes and sizes followed by drying of

these papad pieces to desired moisture content of 7-8% (db). Since the pericarp is not separated out from the starch, it gives a little dark colour to the papad which again upon frying or roasting turns to lighter with good consumer acceptability.

(iii) Puffing or popping

Puffing or popping of cereals is an old practice of cooking grains since time immemorial to be used as snack or breakfast cereal like corn either plain or with some spices/salt/sweeteners. Popping or puffing of finger millet is one of the popular traditional methods and the popped millet and its flour is a RTE product with pleasing texture and appealing flavor. Popping improves the nutritional value by inactivating some of the antinutritional factors and thereby enhancing the protein and carbohydrate digestibility (Nirmala et al., 2000); it also enhances the appearance, colour, taste and aroma of the processed raw material. The flour can be used for different types of RTE food preparations depending upon the taste and likings. For puffing, the whole finger millet grain is conditioned by mixing additional water so as to reach its moisture content in the range of 18-20% and tempered for about 4-6 hours under shed. The conditioned grains are puffed by agitation on the hot sand surface maintained at about 230 - 250 °C for short time following HTST (high temperature and short time) process. During this process, the sugars present in the aleurone layer react with amino acids of the millet causing Millard reaction and as a result, a pleasant and highly desired aroma is developed. Further, during this process, the vapour pressure of the grain increases and the moisture present in the grain turns into steam; gelatinization of the starch takes places and explodes. Since during popping or puffing grains are dehydrated to the extremely low level of moisture content, nearly 3-5%, the shelf-life is enhanced. Now days modern air puffing machines have been developed which can be used for mass production of puffed or popped millet grains. In addition to this, there will be no risk of sticking sand particles with the product in machine popping or puffing.

(iv) Puffed finger millet mix

Puffed finger millet grains can be converted into powder by simple grinding which can further be enriched with additional ingredients. Various combination of ingredients can be taken and mix well, this nutritious mix so prepared forms RTE food. The selection and combination of the ingredients is done based on the requirement of the target groups like children, pregnant and lactating

mothers etc. The ingredients are selected in such a way that no further cooking requires and hygienically packed in suitable packaging materials. The following table give an example of such mix, similar other combination of ingredients can be selected which should be nutritious as well as acceptable to the target group. The mix contains higher amount of protein, energy, calcium and iron with higher bioavailability (Edam et al., 2001).

(v) Malting – Weaning food

Traditionally the millet malt is utilized for infant feeding purpose and also to prepare beverages either with milk of lukewarm water with the addition of sugar since pretty old times. Finger millet being good malting characteristics, its malting is popular in the area of cultivation particularly in Karnataka and part of Tamilnadu. Malting of finger millet improves its digestibility, sensory and nutritional quality as well as pronounced effect in lowering the antinutrients (Desai et al., 2010). Finger millet has some of the inherent qualities which make it superior compare to other cereals and also qualify for malting and preparation of malted foods. It is resistant to fungal infection and elaboration of alpha and beta amylase during germination and during roasting/kilning a desirable aroma as well as is developed which makes it an ideal grain for malt foods. In addition to these, finger millet is a good source of sulphur amino acids and calcium. An example of composite malt flour (malted weaning food) preparation combining finger millet, green gram and bengal gram is presented in the following process flow chart. This blend is nutritional in addition to rich source of protein and calcium.

In the above unit operations, the germination is an important unit operation which needs greater attention. During germination process, the hydrolytic enzymes bring changes in the endosperm. Some of the vitamins are also synthesized and the bioavailability of minerals increases. During soaking, the soak water is required to be changed once or twice to prevent the excessive growth of micro-organisms and also to make it free from CO₂ formed during soaking. During germination, it is essential to mix or turn the grains to provide good aeration to facilitate better germination. Germination period of about 48 hours is desired but in summer it can be reduced to 36 hours. To stop the germination process, the grains are dried either sun or mechanically drying. While drying it should be kept in mind that the drying temperature should not exceed 75°C. Higher drying temperature may cause parboiling effect and

hardening of the grains which may have adverse effect on milling and quality of the malt flour. The sprouted grains should be dried to a final moisture content of nearly 10-12% and subsequently the separation of roots and shoots is done which can be accomplished by various traditional and modern methods by giving a mild rubbing or abrasion action to the grain mass. These grains (malted) are then roasted uniformly at 70-80°C either by conventional toasting pan or heaters. Uniform heating and roasting helps in developing characteristic aroma and desirable quality of the product. The malt so obtained is pulverized to convert it into RTE form. The pulverization can be accomplished by any size reduction facilities suitable to convert into fine flour. The pulverized malt is then subjected to sieving through the fine sieve to separate the husk and fine malt flour is obtained.

The malted weaning food is mixed with powdered sugar, milk powder or whole milk along with flavouring agents to make as milk based beverage. This preparation is a good source of nutrition and suitable for all the age groups. This preparation is popularly known as '*ragi* malt' and can be used as health drink or energy drink. Now-a-days about 5% *ragi* malt is invariably blended with the energy food to improve its texture and mouth feel.

(vi) Noodles – Vermicelli

The changing food habits of children and teenaged groups have created a good market of noodles in India and abroad. The demand for millet noodles particularly the noodles made out of finger millet is growing due to awareness of its nutritional properties. Noodles are the pasta products also known as convenience foods prepared through cold extrusion system which become hard and brittle after drying. The cooking of these noodles is very convenient and requires few minutes. Noodles of different combinations are prepared such as noodles exclusively made of finger millet, finger millet and wheat in the ratio of 1:1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1. In case of exclusive millet-based noodles, pre-treatment to the millet flour is given to facilitate extrusion and smooth texture which should retain while drying and cooking. Generally, in the preparation of noodles, wheat flour is invariably used as an important member of blend because the presence of wheat gluten has an added advantage which not only helps in easy extrusion but also gives a smooth and fissure free texture to the noodles. Several other combinations of blends can

be explored in the preparation of noodles keeping food values of ingredients and their availability in mind.

(vii) Extruded products

Extrusion technology is another novel way of transforming ingredients into value added products. Extruded products prepared from different grains are very popular now days among the all age groups and their demand is growing, one such example is 'Kurkure', very popular among children. The change in life-style is also bringing a drastic change in the food habits, and the extruded foods being RTE products have become a good choice as snack foods. All the cereals containing good amount of starch can be extruded after making flour and conditioning to required condition. Finger millet flour or grits exhibit good extrusion characteristics. Extrusion cooking has ability to gelatinize and cook the product to the fullest extent and enables its uses as a RTE food. In extrusion cooking, the combined effects of shear along with heat and pressure are mainly responsible for the modification of starch properties. The flour/grit with 16-18% moisture content has ability to extrude in the barrel temperature range of 100-120°C well with good expansion index with crunchy, porous and smooth surface texture. Like other preparations, the finger millet flour can be blended with other legume ingredient flours in appropriate proportion with further fortification of minerals and vitamins to design a balanced nutritional extruded food. Alternatively, the extrudates can be pulverized and blended with calculated amount of other pre-prepared/cooked ingredients to prepare supplementary food mix for infant babies and lactating mothers etc. A further value addition of extrudates so prepared from finger millets can be done by coating with sweet or savory to attract children.

(viii) Bakery products

Incorporation of finger millet flour in the preparation of bakery products like biscuit, nan-khatai, muffins and bread has been attempted and efforts are being made to standardize the recipe and product quality. The use of millets in bakery products will not only superior in terms of fibre content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products. In a recent study, attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fibre content by supplementing with malted finger millet flour (Desai et al., 2010). In recent years, finger millet has received attention and efforts are

under way to provide it to the consumers in convenient forms (Singh et al., 2012).

(IX) Fermented foods

Fermented foods like *Dosa* and *Idli* are popular in many parts of India. These are very common as breakfast foods and even as the evening meals in southern part of the country. Finger millet is widely used as one of the ingredient for these kinds of fermented foods. It not only improves the taste but at the same time enriches the food value in terms of protein, calcium and fibre. Sprouting of finger millet grain or the malted grains are also used for fermented foods depending on the taste and choice. *Ragi* flour is blended with the other base ingredients for fermented foods following other procedures.

(X) Ragi Soup

Ragi soup is prepared by mixing the *ragi* flour into water (one part *ragi* flour and 2.5 parts water). While mixing or stirring sufficient is taken so that that should not be lump formation and it should leave a smooth and thick body of mix. This mix is then heated for 15-17 minutes under medium heat or till it is cooked. During heating continuous stirring is needed to avoid any lump formation further. After cooking the mix is removed from the heat and mix with curd (half tea cup) and salt to taste. Leaving it for another 5 minutes it is ready to serve as warm. In case of cold serving, further cooling is required.

(XI) Ragi Pakora (finger millet fritters)

Cut onion lengthwise. Crush the garlic using a knife. Keep them aside. Mix *ragi* flour, crushed garlic, cumin seeds, red chili powder and salt to a bowl. Add 1/2 to 3/4 cup of water to the ingredients and make a more liquid like paste. Add the cut onion to the flour mix and coat it well with the mix. Heat oil in a pan. Once the oil is hot enough, add the flour coated onion to the oil and fry till it becomes crispy. Serve hot.

(XII) Ragi Vada

Chop onion and greens (Keerai). Keep aside. Take a vessel and mix all the ingredients except oil. Add required water and make a soft dough (like chapati dough), but slightly thinner than chapati dough. Heat oil in a pan. Take a small amount of dough, press that with help of fingers and drop that in hot oil. Fry till it turns into crispy or till the bubbles are almost stopped.

In addition to the above preparations, many other local preparations are in practice making use of finger millet depending upon the local habits and choice of the groups, some of them are common

across the regions but some typical products remain in the domain which needs to be popularized. Few modern products incorporating finger millet are now available in the market such as, *ragi* health drink (baby vita), foodles, multi-grain noodle, *ragi* biscuit, *ragi* vermicelli etc.

Finger millet is well comparable and even superior to many cereals in terms of mineral and micronutrient contents. Its major use as food has remained only in the area where it is cultivated and to the traditional preparations (Amadou et al., 2011). Finger millet has good potential of providing nutritional security to the consumers (Singh et al., 2012). Its consumption in urban area can be increased through its proper processing and value addition. With the advancement of post-harvest processing and value addition technologies, it has become possible to process and prepare value added products which are acceptable by both rural and urban consumers. This will not only help in increasing the profitability of its cultivators but will also help in providing income and employment opportunities in rural area.

Conclusion

In conclusion it can be stated that *kodo* and finger millets are staple food in different parts of India and abroad. Apart from, meeting the food requirements of the population of the cultivation catchment, they have sound nutritional and medicinal values. These properties however have not been focused to the residents of the non-millet growing regions. Though the consumption patterns of these millets are very specific and continue to remain regional specific, there popularization in the broader range is essential. Specific design of foods acceptable to the population of the region specific and group specific can help in promoting the millet consumption and thereby nutritional intake of the consumers significantly. This will also contribute to the food basket of the nation in addressing the food security.

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