RESEARCH REVIEW JOURNALS
Volume-04
Issue-01
January -2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com [UGC Listed Journal]

Noodle enrichment-An opportunity for development of noodles with enhanced nutrition

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ARTICLE DETAILS

Article History
Published Online: 20 January 2019

Keywords
Noodle, enrichment, quality, nutrition

ABSTRACT

Noodles are widely consumed product across the globe. Enrichment of noodles offers an opportunity to improve the nutritional quality of the product with improved health benefits. Noodles are considered good food vehicle for addition of bioactive compounds. This review summarizes the opportunities for noodle enrichment with different sources viz. protein, fibre, alternative flours, fruits and vegetables. The effects of noodle enrichment on chemical composition, functional, textural qualities are summarized with emphasis on role of different additives, microstructural studies for probable improvements in noodle quality attributes and consumer acceptability.

1. Introduction

Noodles are one of the staple foods consumed in many Asian countries. Instant noodles have become internationally recognized food, and worldwide consumption is on rise. The major ingredients for preparation of instant noodles are wheat flour, water, salt or *kansui* (an alkaline salt of sodium carbonate, potassium carbonate) while minor ingredients are different additives to improve texture of noodles. Instant noodles are partially cooked and can be dehydrated by air drying or deep frying process. Durum wheat flour (Cuesta*et al.,* 1993) with 11-13% protein content is preferred for preparation of Asian noodles as it gives good sensory quality, color and textural properties (Fu, 2006). According to (CAC, 2016), durum wheat flour shall not contain less than 11% protein. The gluten protein in wheat is responsible for giving the elasticity character and noodle firmness (Karim, 1990). Noodles represent a complex system in which multiple components viz. starch, protein, water and lipid interact under various conditions to achieve final product quality.

The consumer demand for natural, healthy and improved nutritional foods is increasing which is continuously boosting the food industries to come up with more diversified food products in global food market. In this regard functional foods offer an outstanding opportunity to improve the quality of the product. Noodles are recognized by food and drug administration as a good matrix for addition of bioactive compounds (Chillo *et al.,* 2008). For this purpose, development and studying noodle products with good nutritional, functional and acceptability is inevitable work.

The enrichment of noodle like products already began more than five decades ago with the addition of soy protein. Since then, only pastas were enriched with vegetables and legumes with few researches on noodles prepared from starchy materials. Several reasons for the enrichment of noodles have been pointed out in literature, such as nutritional enhancement, use of cereal, fruit and vegetable by-products, use of local raw materials, production of gluten free noodles from non-wheat sources. The noodle enrichment results in the replacement of gluten proteins diluting the starch protein network affecting the functional properties. This review summarizes the sources for noodle enrichment and its effects on chemical composition, cooking, functional properties, and microstructural changes.

2. Protein enrichment

Noodles contain 11-15% protein (dry basis) but are deficient in lysine & threonine like other cereal products. The purpose of adding natural proteins to noodles is mainly for improving nutritional quality and maintaining a strong dough structure. Combination of cereals and legumes were explored to produce nutrition rich noodles. With this aim, lentil based extruded noodles were prepared with acceptable physical and sensory properties (Rathod and Annapure, 2017). Utilization of whole lupin meal & defatted lupin meal (Eman*et al.,*2012), green gram, soy flour and whole egg powder (Jayarathne *et al.,* 2006),amaranthus and buckwheat protein (Feliciano *et al.,* 1998) has been exploited as a source for protein enrichment in noodles. Whey protein concentrate (WPC) and skim milk powder (SMP) showed increased total solid loss with increase in level of substitution (Baskaran *et al.,* 2011). Efforts were also made to utilize by-product from oilseed processing industry i.e.texturized defatted meal from sunflower, flaxseed and soybean at 10% level as good substitute to wheat flour with increased protein content in noodles production Bhise *et al.,* (2015).

Table No. 1 Key findings for protein enrichment in noodles

Sr. No.	Enrichment source	Key findings	Reference(s)
1.	Amaranthus and buckwheat protein	Addition of Amaranthus and buckwheat isoelectric protein concentrate in noodles significantly affected the physical properties of wheat dough but had non-significant effect on physical and cooking properties of noodles.	Feliciano *et al.*, 1998
2.	Green gram, soy flour and whole egg powder	The protein enriched noodle with 10 kg of green gram flour, 10 kg of soy flour, 5kg of whole egg powder and 75 kg wheat flour was selected as the best combination by sensory evaluation. The 85g protein enriched noodle could provide minimum of 14.9% protein.	Jayarathne *et al.*, 2006
3.	Whole lupin meal (WLM) & defatted lupin meal(DLM)	WLM and DLM were used at levels 5–10% and 5–20% respectively to develop protein enriched noodles. The protein efficiency ratio, essential amino acid index, biological value, chemical composition was improved. The fortified noodles were preferred with nonsignificant level than control.	Eman *et al.*, 2012
4.	Whey protein concentrate (WPC) and skim milk powder (SMP)	The enriched noodles prepared from SMP, WPC and combinations were evaluated at 5, 7.5 and 10% levels. Total solid loss increased with increase in substitution level. Due to the compact structure of WPC and porous structure of SMP, the noodles supplemented with SMP showed higher cooking loss compared to other two combinations.	Baskaran *et al.*, 2011
5.	Texturized defatted meal from sunflower, flaxseed and soybean	protein enriched noodles developed from texturized defatted meal from sunflower (10%), flaxseed (10%) and soybean (20%) showed good overall acceptability. Increased substitution affected color, sensory and cooking properties of noodles.	Bhise *et al.*, (2015)
6	Lentil	Nutritionally rich and sensory accepted lentil:rice (40:60) noodles were developed by optimizing extrusion process parameters which resulted in reduction of anti-nutritional factors and improved in-vitro protein and starch digestibility.	Rathod and Annapure, 2017

3. Fibre enrichment of noodles

The primary ingredient in instant noodle making is flour of hard wheat which is low in fibre because of wheat refinement process. Thus, noodles which represent major end use of wheat after breadare suitable for enhancing health by incorporating fibres. Fibre enriched noodles were prepared by incorporation of defatted rice bran (Pakhare K.N. *et al.,*2016).Textural properties of noodles were optimized with partially hydrolysed guar gum as asource of soluble fiber which was found to have a significant effect on the hardness, adhesiveness, cohesiveness, chewiness and resilience (Mudgil *et al.,* 2016). Whole wheat noodles with ground bran particles as a source of fibre has not seen much success mainly because ofdifference in texture and mouthfeel compared to refined wheat flour noodles (Hou Gary, 2010).

Table No. 2 Key findings for fibre enrichment in noodles

Sr. No.	Enrichment source	Key findings	Reference(s)
1.	seaweed puree (E.cottonii, G. verucossa)	The seaweed puree substitution level in noodle formulation was up to 30% of each seaweed. Decrease in protein content and increase in dietary fibre was observed with substitution of seaweed in noodle formulation. Lower tensile strength of substituted noodles indicated that seaweed could not conform as an effective ingredient in network formation with wheat flour.	Eko Nurcahya Dewi(2011)
2.	Gracilaria seaweed powder	Seaweed powder was substituted with wheat flour at 1%, 3%, 5% and 7%. As the level of seaweed powder increased the moisture content of noodles decreased while the ash and fibre content increased than control. sensory scores were acceptable up to 3% level of addition with fibre 1.7% and ash 1.05%.	Xiren (2013)
3.	Defatted kenaf (*Hibiscus cannabinus*) seeds	The noodle samples prepared from defatted kenaf seed flour at 25% and 75% respectively by replacing wheat flour proportionately. Ash, fibre and total phenolic content in kenaf noodles were more compared to the control sample (100% wheat flour). The noodle brightness and hardness values were affected negatively	Zawawi *et al.*, (2014)
4.	Partially hydrolysed guar gum	Partially hydrolysed guar gum (1-5 g/100 g of flour) as soluble fiber source was used in noodles. Optimized formulation with partially	Mudgil *et al.*, 2016

		hydrolysed gaur gum (3.4%) increased the soluble fiber content to 3.62% as compared to control noodles (1.07%).	
5.	Defatted soy flour (DSF)and Defatted rice bran(DRB)	DSF and DRB incorporated noodles showed increased protein, crude fibre and calcium content. Cooking loss, cooking time and water uptake were more compared to control noodles. HDPE packaging demonstrated better shelf life for noodles compared to LDPE.	Pakhare K.N. *et al.,* (2016)

4. Noodles enriched with alternative flours

Many researchers have endeavoured to develop gluten free noodles with rice (Ahmed, Quazi 2015), maize flour (Shobha *et al.,* 2015). Extensive research has also been carried on replacing portion of wheat flour in noodles with alternative flours for enrichment purpose likebuckwheat flour (Choy *et al.,*2013), blends of canna starch & rice flour as a source of prebiotic in rice noodles (Wandee *et al.,*2015).Wheat flour supplementation with unripe banana flour (20.45% banana flour and 47.72% wheat flour) has been tried wxith the aim of increasing the proportion of indigestible compounds such as resistant starch and non-starch polysaccharides (Ritthiruangdej *et al.,*2011).Malted ragi flour supplemented noodles showed higher values of protein, fibre and minerals and were recommended as an instant food for children, teenagers, sport persons, pregnant and lactating women by Kulkarni *et al.,* (2012). One of the perspective for utilization of alternative flours in noodles could be incorporation of finger millet flour in noodles for the management of diabetes disorder which has high proportion of unavailable carbohydrates which slows the release of sugars and thereby responsible for loweringglycaemic index.(Kamini Shukla, 2014).

Table No. 3 Key findings for noodle enrichment with alternative flours

Sr. No.	Enrichment source	Key findings	Reference(s)
1.	Unripe banana flour	The 30% green banana flour substituted noodles showed increase in the dietary fiber and resistant starch contents against the control sample. The color of noodles turned darker, the cooking loss in banana flour noodles was more which could be due to weakening of protein network by substitution.	Ritthiruangdej *et al.,* 2011
2.	Malted ragi flour	Wheat and ragi flour samples (70:30) scored at par on overall acceptability with higher protein, fibre and mineral (i.e. calcium, iron and phosphorous) compared to control sample. The ragi flour supplemented noodles can serve as an instant food for children, teenagers, sport persons, pregnant and lactating women because of good nutrient content.	Kulkarni *et al.,* (2012).
3.	Buckwheat flour	Buckwheat flour addition (0-40%) in Australian soft flour produced softer texture and had minimum effect on Baker's flour. The antioxidant rutin increased with increase in level of addition of buckwheat flour but decreased the color (L*) value of noodles.	Choy *et al.,* 2013
4.	Finger millet flour	The glycaemic index of 30% finger millet incorporated noodles was significantly lower (45.13) than control noodles (62.59) and also scored high in sensory evaluation. Finger millet flour incorporated noodles were found nutritious and showed hypoglycaemic effect.	Kamini Shukla, 2014
5.	Rice	Wheat flour and broken rice flour blended noodles at (20:80) proportion showed highest overall acceptability scores but lower score for appearance and texture in different blends. The noodle sample with only wheat flour showed highest preference over blended samples.	Ahmed, Quazi 2015
6.	Cassava, protein rich flours	The oilseeds like melon seeds, soybeans, bambara groundnut and peanut were solvent extracted to get protein rich flours. The noodle samples were prepared with 80:10 ratio of wheat: cassava flour and 10% each of protein rich oilseed flour. The cooking time, cooking loss, cooking weight, and sensory of samples of all samples had significant difference compared control (wheat flour) sample. The good quality enriched noodle can be prepared from wheat flour: cassava flour: soybean flour in 80:10:10 proportion.	Omeire *et al.,* (2015)
7.	Maize flour	Maize flour can be substituted up to 50% level with other minor ingredients to obtain better quality noodles. Protein, soluble and insoluble fibre content found to be good compared to control noodles.	Shobha *et al.,* 2015
8.	Canna starch and its	The cross-linked canna starch showed potential for increasing tensile	Wandee *et al.,*

	derivatives (retrograded, retrograded de-branched, and cross-linked)	strength of rice noodles while the total dietary fiber content of noodles prepared from retrograded de-branched starches was highest (7.3%). The capability of producing SCFAs and butyric acidwas superior in retrograded de-branched starch (20%) noodles compared to control rice noodles.	2015

5. Fruit &Vegetable enriched noodles

Noodles are deficient in dietary fibre, vitamins & minerals. One of the possible solutions to compensate this deficiency could be enrichment of noodles with fruit & vegetables which are good source of fibres,minerals, vitamins, carotenoids, polyphenols which can generally be termed as phytochemicals. Considering the percentage addition, fruit & vegetable noodles can significantly contribute to the recommended vegetable intake per day which can increase children's intake of health promoting foods such as vegetables but incorporating high volume of vegetables in noodles has a significant effect on physical, sensory, functional properties & stability (Elisabete *et al*. 2013).

Enrichmentof noodles withstinging nettle *(Urtica simensis)* leavesand wheat flour blend15%w/wimprovedprotein, ash, fiber, Ca, Fe and Zn contents and sensoryattributes compared to control noodles (Dagem, 2016), utilization of underexploited jack fruit (Veena kumari *et al.,* 2015), trifoliate yam (*Dioscorea dumetorum*) (Akinoso *et al.,* (2016) in noodle were studied. Apple pomace powder was used in formulation of noodles which exhibited increase in total dietary fibre and protein content of the noodles and improved antioxidant activity (Yadav and Gupta, 2015).Incorporation of high volume fractions of dispersed vegetables in noodle products has a significant effect on their physical properties and stability. For this reason Elisabete *et al.,* (2013) investigated the rheological properties of gelled protein and starch matrices with high volume fractions of vegetables (up to 25 %). Incorporation of broccoli powder in sweet potato starch noodles increased the modulus of dough, stiffness and strength of noodle due to swelling of broccoli particles 7.6 times their original value (Silva *et al.,* 2013).

Table No. 4 Key findings for fruit and vegetable enriched noodles

Sr. No.	Enrichment source	Key findings	Reference(s)
1	Banana peel flour	Banana peel flour was substituted at 10% level with wheat flour. Color of treated noodles was dark compared to control sample (wheat flour). In-vitro starch digestibility of substituted noodles exhibited low glycemic index compared to control which may be due to higher dietary fibre and resistant starch content in banana peel flour.	Saifullah *et al.,* (2009)
2.	Cassava, soy flour and carrot powder	All the ingredients (50: 20: 20: 10 – Wheat: Cassava: Soy: Carrot flour) were blended to obtain the enriched noodles. The protein content of sample with soy flour was high.Total carotenoid content of noodle sample with 10% dried carrot was 1.8mg/100g dry weight basis with appealing color of final product.	Adegunwa *et al.,* (2012)
3.	Broccoli powder	Addition of broccoli powder 20% v/v caused increase in modulus of dough, strength and stiffness of noodles. Broccoli particles can swell up to 7.6 times their original volume affecting the microstructure of starch noodles.	Silva *et al.,* 2013
4.	Jackfruit Seed and soy flour	The noodles were developed with 100:00:00, 90:5:5, 80:10:10, 70:15:15, 60:20:20, 70:10:20 and 70:20:10 proportions of refined wheat flour, jackfruit seed flour and soy flour respectively. The supplemented samples contained elevated levels of protein, fat and ash. Noodles with 90:5:5 proportions of refined wheat flour, jackfruit seed flour and soy flour were found more acceptable for development of supplemented noodles.	Nandkule *et al.,* 2015
5.	Apple pomace	Apple pomace (by-product of apple processing industry) was incorporated in noodles at 10, 15 and 20% levels. 10% incorporation level was found better. The chemical composition of noodles showed improved protein (11.8%) and dietary fibre (13.28%) content compared to control. The cooking quality revealed that cooking loss and swelling index increased in apple pomace incorporated noodles. Apple pomace incorporated noodles can be a good source of nutraceuticals with increased content of polyphenol and dietary fibre.	Suman Yadav *et al.,* 2015
6.	Jack fruit	Underexploited jackfruit noodles can be prepared with refined flour: bulb flour: seed flour (50:10:40) and (50:20:30). However, the control wheat flour noodles were more acceptable than the jackfruit noodles.	Veena kumari *et al.,* 2015
7.	Trifoliate yam	Underexploited trifoliate yam flour at 20-50% levels showed sensory	Akinoso *et al.,*

		acceptability at par with control wheat noodles except for taste and color of dried noodles.	2016
8.	Stinging nettle leaves	Nettle leaves (dried powder) being good source of protein and mineral could be utilized for incorporation in noodles up to 15%. However, addition of nettle leaves significantly decreased the sensory acceptability of noodles.	Dagem, 2016

6. Improvement of functional properties with additives

Noodle enrichment with fibres or fruit and vegetable or alternative flours often affects the perceived texture of noodles.It was speculated that the changed texture perception results from a disrupted gluten matrix due to the presence of fibre particles (Manthy & Schorno, 2002) or through increased physical or chemical interaction between fibre and gluten (Noort *et al.,* 2010). Common additives added in noodles for improving the texture arepotato starch, sweet potato starch, tapioca starch and corn starch (Muhammad *et al.,* 1999) which aremainly used for improving the appearance, surface smoothness and mouthfeel of final product (Konik *et al.,* 2006). Dry gluten powder, whey protein, egg albumen are few natural proteins which are added to noodles for the purpose of improving nutritional quality, maintaining strong dough structure and improving the chewiness of final product (Maforimbo *et al.,* 2008). Edible gums namely guar gum, algi, xanthan gum, locus bean gum will affect the tenacity of the protein-starch matrix and thus, affect the cooking and eating qualities of noodles. They act as gluten enhancer, resulting in a stronger dough structure improving the noodle texture (Man Li *et al.,* 2014).Texture is the most important property for consumer acceptance in cooked noodles.Researches have been focusing on improving the air dried noodle quality with respect to cooking characteristics, sensory attributes and textural properties with additives (5 g oil, 0.2 g guar gum, 2 g gluten and 1 ml of 1 % kansui solution for 100 g of wheat flour) and steaming treatment (Gatade and Sahoo, 2015). Maltodextrin (5 g/100 g of wheat flour)incorporated into the noodle formulation was effective in improving the rheological characteristics of noodles by increasing their maximum force to extension and extensibility,cooked noodles exhibited higher thermal conductivity and lower firmness, possibly indicating shortened cooking time (Jang *et al.,*2016).

7. Microstructural changes in enriched noodles

Noodle flours enriched, fortified or substituted may result in changed texture perception due to disrupted gluten matrix. For example, noodles enriched with fibres may lack in compactness and elasticity of gluten network as a result of which starch granules can swell easily during cooking causing stickiness and more soluble matter loss into cooking water. Therefore, it is important to study the microstructural changes in noodles to justify the cooking properties of enriched noodles. The mechanism of molecular interactions has been brought about by improved imaging techniques. Recently, confocal laser scanning microscopy (CLSM) could be regarded as a potential tool for understanding the effect of processing and the influence on bio-macromolecules. Microstructural characteristics have been studied using CLSM, magnetic resonance imaging (MRI), scanning electron microscopy (SEM) to monitor microstructural differences (Dürrenberger, *et al.,* 2001; Sangpring, *et al.,* 2015).

8. Conclusion& future perspectives

Noodles are an important basic food widely consumed across the world.Food and drug administration has recognized noodles as a good vehicle for addition of bioactive compounds. Noodles are deficient in fibre, protein, vitamins and minerals. Therefore, enrichment of noodles is need of today's era. Various enrichment sources viz. protein, fibre, alternative flours, fruits and vegetables provide an opportunity to enhance the nutritional benefits of noodles. The major challenge in developing enriched noodles is consumer acceptability which can be addressed through improving functional, textural, cooking and sensory properties of noodles. Incorporation of additives, microstructural studies and probable changes in noodle processing may help minimize the challenge.There are many opportunities yet to be tapped in the category of noodle enrichment with bioactive compounds focusing on functional health benefits.

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