Alternate Food Sources for Modification of Digestibility of Common Foods Author: Vikono Ksh, Shalini G. Rudra\*, R.R. Sharma

Common foods such as bread, pasta, noodles, etc. are widely consumed by the majority of the world's population. The increase in lifestyle diseases (diabetes, obesity, etc.) coupled with the global awareness on these issues has led to a high demand for foods with lower glycemic index. Glycemic Index (GI) is a number associated with a particular type of food that indicates the food's effect on a person's blood glucose level. A value of 100 represents the standard (pure glucose). Based on the GI, food can be classified as:



Fig. 1. Classification of food based on GI.

One of the best ways of developing food with improved health benefits is by the incorporation of alternate food sources having higher resistant starch fractions such as banana pseudo-stem flour (BPF), sweet potato flour (SPF), barley flour, etc. in the commonly consumed foods. Besides this, the incorporation of newer sources of food leads to enhancement of nutraceuticals value of these common foods. For instance, resistant starch (RS) incorporation in food system is becoming increasingly popular as it promotes colon health by the production of short chain fatty acids and reducing pH. RS remains un-hydrolyzed even after 16 hour of ingestion and hence acts as a dietary fiber.

Knowledge about the complex physicochemical and physiological events that occur in the human gastro-intestinal tract is important when a novel fortified food product is developed. This can be achieved by implementing the various *in vitro* digestion models available. Though not very accurate, *in vitro* digestion models provide an alternative method of screening the food

ingredients by mimicking the human digestion process (Coles *et al.*, 2005). In this review, we seek to elaborate the methods for *in vitro* digestibility estimation adopted by researchers for low GI foods development. Also some techniques for improvement of quality of these foods through use of hydrocolloids are presented.



Fig. 2. Illustration of *in vitro* digestion.

One such example of incorporation of RS is Nutriose <sup>®</sup> which is partially hydrolyzed starch from wheat or corn. Having non-viscous soluble nature, Nutriose is gaining acceptability among processors as a RS rich food additive. Lefranc-Millot (2008) have reported that during the controlled process of dextrinization, the starch undergoes partial hydrolysis to dextrin, followed by repolymerization which imparts the properties of resistant starch to Nutriose. It is a good source of soluble fiber which has found health benefits in gluten-free bread-making (Martinez *et al.*, 2014)



## Fig. 3(b). Sweet potato starch noodles formulation.

Menon *et al.* (2015) investigated the effect of incorporation of Nutriose® in noodles made from sweet potato flour and sweet potato starch. Regarding this commercial RS, it was reported to have high digestive tolerance, low GI (<25) and good stability. Pale cream fleshed sweet potato (Sree Arun variety) was used to obtain sweet potato flour (SPF) and sweet potato starch (SPS). Two types each of SPF and SPS based noodles were prepared containing NUTRIOSE<sup>®</sup> at different levels. The treatment with the lowest glycemic index was further modified by the incorporation of guar gum. The formulation used is summarized in fig. 3(a) and 3(b).

*In vitro* starch digestibility was evaluated as per summarized protocol (Fig. 4). Glucose released was quantified by glucose oxidase method (EC 1.1.3.4) – PAP method.



**Fig. 4.** *In vitro* digestion protocol (Renjusha *et al.*, 2014). Panzynorm®- 10,000 U lipase, 9000 U α-amylase, 500 U protease. Dextrozyme®- glucose amylase (intestinal enzyme).

Cooking loss (CL) was significantly reduced for 10% NUTRIOSE fortified SPF noodles, compared to the control SPF noodles. Significantly higher CL (%) was observed for 20%

NUTRIOSE. Swelling index was also the least for the 10% NUTRIOSE fortified SPF noodles. NUTRIOSE might be forming a complex with gluten which then encapsulates the starch granules, so that they undergo only restricted swelling (Colonna *et al*, 1990 and Fardet *et al*, 1997). Beyond 10% level, the excess NUTRIOSE might be only forming a loose network, which caused higher swelling on cooking.

In the case of SPS noodles, NUTRIOSE addition lead to increased CL probably because of the binding between WPC and NUTRIOSE, leaving the starch to gelatinize freely and leach in the cooking water. Guar gum (0.5–1%) fortification to 5% NUTRIOSE fortified noodles could reduce the CL significantly. Guar gum supplementation (1%) could significantly reduce the swelling index (SI) of 5% NUTRIOSE fortified SPS noodles.

Starch digestion kinetics revealed that the digestion proceeded very slowly in the test noodles and after 120 min., only 53–68 g glucose were released. Further guar gum (GG) incorporation at 1% level resulted in the drastic reduction in starch digestibility. In case of SPS noodles, *in vitro* starch digestion progressed much slowly than the SPF noodles. NUTRIOSE at 5% and 10% level exerted a highly significant effect in reducing the digestible starch (RDS + SDS), and in increasing the RS in the products. This effect was further complemented by GG addition to a greater extent by 0.5% GG, unlike in the case of SPF noodles, where 1% GG + 15% NUTRIOSE, exerted a greater effect in elevating the RS content.

The estimated glycemic indices (EGI) was significantly brought down in the SPF noodles by fortifying the SPF with RS rich NUTRIOSE and the least value of 55.23 was obtained for 15% NUTRIOSE. This was further reduced to 54.58 to obtain a truly low glycemic product, by adding 1.0% GG to the 15% NUTRIOSE mix compared to control SPS noodles with EGI of 62.95.

Soluble fibres like  $\beta$  glucan primarily from oats and barley can also be used to lower the digestibility of foods besides providing their nutraceutical benefits like hypocholesterolemia. Barley flour usually contains about 2-10% of  $\beta$ - glucan (w/w) (Bamforth, 1982). According to FDA, dietary intake of 3 g/day  $\beta$ - glucan can reduce the total cholesterol and the blood glucose level. Many researchers like Moza and Gujral (2016) and Soong *et al.* (2014) have found barley to be a better source of soluble dietary fibre for modifying digestibility of common foods like muffins, breads and cookies. The effect of enrichment of ditalini pasta with barley flour (40%)

on the quality characteristics and *in vitro* digestibility has been reported by Montalbano *et al* (2016). The elaborate *in vitro* digestion protocol adopted by them has been summarized in Fig. 5 (Tesoriere *et al* 2008). Briefly, ditalini pasta (20g) was cooked and separated from cooking water to obtain pasta asciutta.

Though the BF-ditalini appeared darker than the control, inclusion of BF did not affect remarkably the pasta quality. The incorporation of BF resulted in a compact starch-protein network that delayed disintegration of the matrix during cooking, thus preserving its quality.

With respect to the control, BF-pasta asciutta, having 2.5%  $\beta$ -glucan fiber, caused a decrease of glucose released at 20 min. However, no other significant change was observed thereafter. On the contrary, release of glucose was significantly lower for BF-pasta soup with respect to control soup. These findings indicate that, only BF-soup, containing 5% of  $\beta$ -glucan, significantly decreased the glycemic potency of BF-ditalini. Delay in the starch hydrolysis of pasta added with soluble fiber can be attributed to changes in its microstructure and to hydration of the polysaccharide matrix which hinders encapsulation of the protein-starch matrix until the later stages of digestion.



Banana flour has been successfully incorporated in bread-making (Juarez-Garcia *et al.*, 2006), pastas (Ovando-Martinez *et al.*,2009) while banana pseudostem flour has been incorporated in cookies (Ambrose *et al.*, 2016)

Having high fibre content (Abdul Aziz *et al.*, 2011), Banana pseudostem flour (BPF) can be used as an alternative food source for improving the health benefits of common foods such as bread. BPF has been found to be a good source of macro minerals such as K, Na, Ca, Mg and P (Ho *et al.*, 2012). However, incorporation of BPF leads to gluten dilution which has a negative impact on the bread quality. Hydrocolloids such as xanthan gum and sodium carboxyl-methyl cellulose (CMC) at 0.8% levels were employed to alleviate these effects. The *in vitro* starch digestibility of the samples was carried out according to the procedure proposed by Goñi *et al.* (1997).

The composite breads were found to contain higher amount of Na, Ca, P, K, Mg, Fe and Mn as compared to the control bread. The composite breads had lower total starch content (75-79%). In general, RS in bread samples were found to increase in the presence of hydrocolloids. In breads with CMC along with BPF, the RS content increased to 14.98% as compared with BCtr due to the presence of Na CMC, a soluble cellulose derivative. The interaction between the added fibers and the biopolymers may have resulted in a compact structure in the bread crumb which resulted in the entrapment of starch and thus reducing its accessibility by the enzymes and hence its liberation.

*In vitro* starch hydrolysis showed that the composite breads had lower glycemic response (0.3-2.6%). Addition of different hydrocolloids resulted in a decrease in GI by 68-77% because hydrocolloids are capable of retarding the enzymatic hydrolysis by coating the surface of the starch granules. These act as a physical barrier to the enzyme attack as well as to the release of hydrolysis products.

## FUTURE THRUST

Further research needs to be conducted on the alternative food sources and their utilization in improving the health of the consumers. The use of alternate food sources is fairly a new concept and hence, very limited literature regarding the toxicological and anti-nutritional factors is available. This need to be established for such sources. Technological interventions to improve the quality of common foods containing resistant starch or slowly digestible starch require urgent attention.

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