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Effect of fermentation on nutritional content of common Indian origin pulses and its effect on health and diseases: Review

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Abstract

Fermentation has a high potential to improve the nutritional quality of the pulses, providing protein, starch, fibre, and other health-promoting compounds with physiological benefits that contribute to reducing several risk factors associated with diabetes, cardiovascular diseases, colon cancer, stress, and aging. Pulse-derived fermented products can be considered as probiotic carriers and benefit the health of gut. Given that governments and health organizations recognize the nutritional benefits of pulses globally, it is recommended that fermented pulses address malnutrition and be promoted as a part of healthy eating. Scientific evidence is thus increasingly required to support future health claims for fermented pulses. This review focuses on the changes that take place when a pulse is fermented and how fermented-pulse items should be viewed as part of a balanced, nutritious diet. The growing evidence of the possible beneficial effects of pulse-derived fermented products on the prevention of chronic diseases will also be discussed.

Keywords: fermentation, potential, nutritional, health-promoting

Introduction

Fermentation is an inexpensive and compatible process for transforming and improving the quality of raw and poor digestible legumes into more desirable, palatable, clean, nutritious, and safe edible products with added value. The microorganisms involved in legume fermentation hydrolyze and metabolize seed constituents resulting in the production of derived-value products and are capable of producing antimicrobial compounds and beneficial organic acids that can preserve the food by suppressing the growth and survival of undesirable microflora. Fermentation, therefore, provides many advantages over other traditional legume processing methods, besides being less expensive (Leroy and De Vuyst, 2004) [24].

For decades there has been a large variety of pulse-derived fermented foods. The micro-organisms involved in legume fermentation hydrolyze and metabolize constituents of the pulses resulting invaluable products being produced. Pulses fermentation promotes beneficial improvements, including enhanced nutritional value and sensorial properties, and increased nutrient and phytochemical bioavailability, and facilitates the growth of new bioactive compounds. (Frias *et al*., 2017) [12]

For most developed countries, the daily diet is mainly based on cereals. The main staple foods are wheat, rice, and millets. Though these diets are adequate in iron, their poor bioavailability is one of the most important factors for anemia with an iron deficiency. Modern methods such as fermentation show promise in enhancing the bioavailability of iron. *In vitro,* ionizable iron was estimated in 31 different combinations of rice, wheat, sorghum, black gram, Bengal gram, green gram, and coriander in five replicates with or without, fermentation in steamed products. Results indicate that in general cereal pulse combination and fermentation significantly ($P < 0.05$) increase the percent ape of ionizable iron. Combination effects dominated in rice whilst fermentation dominated in sorghum. There was a significant reduction ($P < 0.05$) in phytate phosphorus on fermentation but no loss of tannin. (Indumadhavi *et al*., 1992) [20]

Table 1: Indigenous Pulse-Based Fermented Foods of India

Product	Substrates	Fermentation Type	Main Microorganisms Involved	Recipe
Dhokla	Chickpeas, green gram, rice (2,2,1)	Liquid-state fermentation	Lactobacillus fermentum, Leuconostoc mesenteroides, Streptococcus faecalis	Ingredients are mixed and fermented naturally for 10–12 h
Dosa	Black gram and rice (1,1)	Liquid-state fermentation	Leuconostoc mesenteroides, Lactobacillus delbrueckii, Lactobacillus fermentum, Streptococcus faecalis, Bacillus spp., yeasts	Soaked dhal and parboiled rice fermented for 10–12 h
Idli	Black gram and rice (1,2)	Liquid-state fermentation	Leuconostoc mesenteroides, Lactobacillus delbrueckii, Lactobacillus fermentum, Lactobacillus lactis, Pediococcus cerevisiae, Streptococcus lactis,	Soaked dhal and parboiled rice are fermented for 10–12 h

			Streptococcus faecalis, yeasts	
Khaman	Chickpeas	Liquid-state fermentation	Leuconostoc mesenteroides, Lactobacillus fermentum, Lactobacillus lactis, Pediococcus acidilactici, Bacillus spp.	Ground dhal is fermented for 10–12 h
Wari	Black gram or bengal gram	Liquid-state fermentation	Saccharomyces cereviseae, Candida krusei, Lactobacillus ssp., Leuconostoc mesenteroides, Lactobacillus fermentum	Ground soaked dhal is backslopped for 1–3 days and ball molded

Changes in Protein and Amino Acids During Fermentation

In dosa production, black gram fermentation resulted in a small increase in proteinase activity increasing total nitrogen, soluble proteins (Soni *et al*., 1985) [38], and well-balanced amino acid batter with approximately 50percent of essential amino acids over total amino acids. (Balasubramanian *et al*., 2015; Palanisamy *et al*., 2012) [7]. In terms of total nitrogen, phosphorus, and free amino acids, replacing black gram with mung bean provided more nutritious batters (Soni and Sandhu, 1989) [39]. Idli products have greater limiting amino acid scores and digestibility of proteins in vitro than non-fermented seeds (Riat and Sadana, 2009) [34]. After pulse fermentation, protein inhibitors are significantly reduced, which leads to improving the overall quality of protein. Trypsin inhibitory activity was largely removed from cowpeas, soil beans, and chickpeas during the preparation of tempeh-like products, and a concomitant increase in protein digestibility was achieved. (Abu-Salem and Abou-Arab, 2011; Hemalatha *et al*., 2007; Egounlety and Aworh, 2003) [1, 18, 13].

Chickpea

Fermentation increases the protein content of chickpea in products such as dhokla by increasing the levels of limiting amino acids (Zamora and Fields 1979a) [48] and thiamine and riboflavin, two major B-vitamins that are typically not consumed in adequate amounts to meet daily needs in India (Aliya and Geervani 1981) [3].

Table 2: Nutrient contents of non-fermented and fermented chickpea flour and chips.

	Flour		Chips	
Factors analyzed	**Raw**	**Fermented**	**Non-fermented**	**Fermented**
Relative nutritive value (percent)	83.27	91.65	83.70	91.74
Methionine (mg N g- 1)	1.611	10.41	0.03	8.42
Isoleucine (mg N g- 1)	2.22	18.83	2.32	16.22
Tryptophan (mg N g- 1)	13.13	16.07	10.66	13.29

Source: Zamora and Fields 1979b.

Pigeon pea

Laboratory studies at ICRISAT have shown that fermentation in Pigeon pea has increased the concentrations of soluble nitrogen and soluble sugars, suggesting that fermentation may boost the digestibility of protein and starch. Fermentation had significantly reduced the activity of trypsin and chymotrypsin inhibitors in Pigeon pea. So, because pigeon pea is eaten in various types of food, the strength and length of the heat treatment it receives during cooking depends on the preparation process. It would also be especially useful to know the nutritional changes caused by various forms of heat treatments and other pre-treatment such as fermentation and germination. (Rajalakshmi *et al*., 1967) [32]

Pigeon pea products' true digestibility (TD) may be enhanced by boiling or fermentation with a fungus (Rhizopus sp). The TD of raw pea pigeon (70.9 percent) increased after boiling to 84.7 percent, and after fermentation to 86.6 percent. However, the raw pigeon pea biological value (BV) decreased from 83.0 percent to 50.6 percent when boiling and 45.6 percent when fermenting. (Widowati and Damardjati 1985) [10].

Black gram Dal

Microbiological, physicochemical, and biochemical changes were investigated for the fermentation of black gram and rice blend. During fermentation total soluble solids, soluble nitrogen, and soluble acids increased while soluble sugars decreased. Trypsin inhibiting activity was unchanged though activity inhibiting chymotrypsin was slowly decreased during the fermentation process. With the increased fermentation time, the batter's amino acid content was increased except for isoleucine and cysteine. Methionine content increased by 60 and 420percent at 20 and 45 h fermentation, respectively. Enzyme digestion with pepsin and pancreatin during fermentation indicated an improvement in the availability of essential amino acids. Fermentation thus seemed to improve the nutritional quality of the proteins in the blend of black gram and rice. (Padhye *et al*., 1978) [28]

Changes in Starch, Carbohydrates, and Dietary Fiber During Fermentation

Fermented pulses provide significant carbohydrate sources (50–70percent) (Abu-Salem and Abou-Arab, 2011; Sotomayor *et al*., 1999) [1, 40]. During starch hydrolysis, amylose and amylopectin slowly decrease during fermentation and sugar reduction. (Audu and Aremu, 2011; Soni and Sandhu, 1989; Sotomayor *et al*., 1999) [38, 40]. In this case, the LAB glucose metabolism resulted in a decrease in the pH associated with the production of lactic acid (Leroy and De Vuyst, 2004) [25].

Fermented pulse products are recognized as a good source of Resistant Starch (RS) (8–15percent) (Granito and Álvarez, 2006; Veena *et al*., 1995) [17, 44]. For example, chickpea *tempeh* contains RS levels three-fold higher than raw flour (Angulo-Bejarano *et al*., 2008) [4]. *Idli* products have been identified as one of the major RS providers in Indian populations (Kavita *et al*., 1998) [22].

Soy food products

Fermentation or digestion of soybeans or soy products results in the release of the sugar molecule from the isoflavone glycoside, leaving an isoflavone aglycone. Soy isoflavone aglycones are called genistein (5,7,4’ -trihydroxyisoflavone), daidzein (7,4’ -dihydroxyisoflavone), and glycitein (7,4’ dihydroxy-6- methoxyisoflavone), sometimes also referred to as isoflavonoids. Fermentation destroys protease inhibitors and cleaves the glycoside bond to yield absorbable aglycone in the processed soy products, such as miso, natto, soy milk, tofu; and increase shelf lives. (Zaheer *et al*., 2017) [47]

Soybean is processed into tempeh by fungus mediated fermentation. This way of processing reported an increase of aglycones amount with a fermentation time of tempeh, approximately two-fold higher after 24 hours fermentation. Likewise, a combined process of fermentation and refrigeration 525 also recorded an increase in aglycone forms (Chen and Wei, 2008; Astuti and Dalais, 2000; Ferreira *et al*., 2011) [8, 5, 14].

Tempeh Prepared from Pigeon pea, and Pigeon pea/Soybean Mixtures

Tempeh is a traditional Indonesian food that is commonly prepared from soybeans by fermenting soaked, dehulled, and cooked seeds, with Rhizopus oligosporus, a mold that spreads not only on the surface but throughout the seeds converting them into a compact cake. During soaking, when bacterial fermentation occurs (Mulyowidarso *et al*. 1989) [27], and during the subsequent mold fermentation, enzymes from these organisms decompose proteins, carbohydrates, and lipids, thereby improving the digestibility, nutritional value, and palatability of the beans (Steinkraus *et al*. 1983).

Changes in Phytic Acid and Mineral Bioavailability During Fermentation

In this context, typical Indian idli and dosa breakfasts have been noted to have a 69 percent reduction in phytic-acid content and an improvement in the availability of Ca and Fe (Krishnamoorthy *et al*., 2013) [23]. The bio accessibility of Zn in these fermented products increased by 71percent and 50percent respectively, and by 277percent and 127percent respectively, to a greater degree, the bioaccessibility of Fe (Hemalatha *et al*., 2007) [19]. Such foods are well-accepted and recommended for malnutrition for Indian children (Dahiya *et al*., 2014) [9].

Changes in Vitamins During Fermentation

Indian *dosa* batters provide larger thiamine, riboflavin, and cobalamin content than unfermented products, and the replacement of black gram by mung beans exhibited higher B-group vitamin content (Soni and Sandhu, 1989) [39]. Besides, vitamin E content increased during natural cowpea fermentation (Doblado *et al*., 2003) [12], while it slightly decreased in fermented pigeon peas and lupins (Frias *et al*., 2005; Torres *et al*., 2006) [15].

Fermented items such as tempeh and natto have been recognized as nutritious, useful foods. The fermentation process makes B-vitamins more available in these products. During fermentation, starch is digested by releasing enzymes. (T. Karki, 1991) [42]

Role of Fermented Pulse Foods in Health Promotion

Plant-based diets are considered part of a healthy diet, providing elements that slow down, among others, chronic diseases such as obesity, diabetes, and cardiovascular disease **(**Pistollato and Battino, 2014) [31]. In general, diets high in fiber, low in energy density and glycemic load, moderate in protein, low in fat, and rich in antioxidants have been found to promote health and well-being (García-Fernández *et al*., 2014) [16]. Fermented pulse foods fulfill these criteria and can have beneficial effects on the prevention and control of highly prevalent pathologies. Furthermore, fermented pulse products contain beneficial probiotic microorganisms that can improve the health of the gut and the associated diseases. While there is adequate documentation of the nutritional benefits of fermented pulse constituents, the scientific evidence showing the role of fermented pulse consumption in disease prevention is scarce. This is possibly due to the worldwide abundance of fermented pulses, and the lack of interventional studies in communities that eat fermented pulses. This summa segment, therefore, criticizes the latest empirical evidence supporting the possible health benefits of fermented pulses.

Fermented Pulse-Products and Diabetes

For nutritional methods, pulses are interventional foods to control blood glucose levels. Pulses have high amounts of RS, generally known as non-digested starch products in the small intestine, which eventually contributes to lower GI and insulin resistance (Messina, 2014) [26]. Lower GI and insulin resistance contribute to both the incidence and severity of type 2 diabetes, one of the factors involved in metabolic syndrome also associated with adipose deposition, dyslipidemia, and hyperglycemia in the waistline. (Alberti *et al*., 2009) [2]. Mung beans were recommended as a portion of potential antidiabetic food for diabetic patients among traditional pulses, and fermented foods also help to reduce the prevalence of diabetes in Asian populations (Yeap *et al*., 2012) [46]. Additionally, its higher GABA content and free amino acids were due to the antihyperglycemic effect of fermented mung bean extracts observed in an alloxan-induced-diabetic mice model (Yeap *et al*., 2012) [46]. Although these findings provide tentative evidence to support the results found in preclinical studies on the impact of fermented pulses on diabetes human clinical studies are encouraged.

Fermented Pulse Products and Weight Management

Overweight and obese individuals are at risk for multiple medical problems that lead to morbidity and mortality, including diabetes, cardiovascular diseases, and other complications of metabolism. A normal energy deficiency contributes to weight gain over time, and low-energy-density diets can help avoid unnecessary weight gain. The replacement of energy-dense foods with pulses can increase satiety (Rebello *et al*., 2014) [33].

To date, there are few published studies devoted to the effect of fermented-pulse products on appetite and satiety. Only one study has shown that *idli* received the best satiety score compared to other breakfast foods that did not include fermented pulses. The satiety scores were positively influenced by the various factors examined for their influence on satiety scores, fiber content, energy density, and food item weight (Pai *et al*., 2005) [29]. Furthermore, fermented pulses provide a strong source of proteins, peptides, and amino acids, making them candidates for weight loss by fullness sensation (Iwashita *et al*., 2006; Lejeune *et al*., 2006; McKnight *et al*., 2010) [21]. While studies are still underway on fermented pulse-derived products, their composition suggests they can modulate biological processes that counteract obesity.

Fermented Pulse-Derived Products and Cardiovascular Diseases

Some fermented-legume products can contribute to a reduction in the risk of cardiovascular diseases due to their effects on blood pressure. In a recent study L fermented navy bean milk. Bulgaricus and Lactobacillus plantarum B1-6 displayed the inhibitory activity of an angiotensin-I converting enzyme (ACE), an effect due to bioactive peptide presence. (Rui *et al*., 2015) [45] Likewise, mung bean milk fermentation per L. The development of smaller and more hydrophilic peptides with higher inhibitory ACE activity resulted in Plantarum B1-6 (Wu *et al*., 2015). LAB strains have also been identified as major producers of GABA, and legume fermented products containing these amino acids can, therefore, exert hypotensive effects. (Dhakal *et al*., 2012) [11].

The research was undertaken to study the hypocholesterolemic effect of an indigenously produced cereal-pulse food mixture fermented with probiotics. Mice have been used as animals in the experiment. An indigenous food mixture has been developed that contains barley flour, sprouted green gram paste, milk coprecipitate and tomato pulp (in the ratio of 2:1:1:1 w/w). The control group was supplied with 1percent added cholesterol to unfermented food mixture while the experimental group received sequentially fermented food mixture (S. boulardii + L. casei) with 1percent added cholesterol. The feeding trial took 42 days to complete. Using kits (Boehringer Mannheim Gm bH, Mannheim, Germany), serum cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides were analyzed. Feeding of the fermented food mixture substantially decreased mean values for concentrations of serum cholesterol and LDL cholesterol in mice. Less affected were HDL cholesterol and triglycerides. In the experimental group, the liver weight as well as the concentration of liver cholesterol was lower compared to the control group although the differences were not significant. Such a food mixture will be commercially viable, as it is healthy, nutritious, and has therapeutic applications. (Sindhu *et al*., 2003) [37]

Conclusion

Pulses are edible seeds of the Leguminosae family (Fabaceae), which include important grain species in their importance for human nutrition which rank second after cereals. Pulses are characterized by their unique nutritional value as a source of proteins, carbohydrates, fibre, vitamins, minerals and phytochemicals with health benefits that are recognized. Cooked, roasted, germinated, and fermented pulses are eaten and form a major part of the daily diet of most of the world's population. Pulse-derived fermented products in different regions of the world vary widely because of well-defined preferences

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