Trends in Food Science & Technology 66 (2017) 73–83

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Review

Why do millets have slower starch and protein digestibility than other cereals?

George Amponsah Annor [a,*], Catrin Tyl [a], Massimo Marcone [b], Sanaa Ragaee [b], Alessandra Marti [a,c]

[a] Department of Food Science and Nutrition, University of Minnesota, 1334 Eckles Avenue, Saint Paul, MN, United States
[b] Department of Food Science, University of Guelph, 50 Stone Road East, Guelph, Ontario, N1G2W1, Canada
[c] Department of Food, Environmental and Nutritional Sciences, University of Milan, Via G. Celoria 2, 20133 Milan, Italy

A R T I C L E I N F O

Article history:
Received 2 March 2017
Received in revised form
6 April 2017
Accepted 22 May 2017
Available online 1 June 2017

This publication is dedicated to the memory of Koushik Seetharaman (1966–2014).

Keywords:
Glycemic index
Millet
Starch digestibility
Protein digestibility
Processing

A B S T R A C T

Background: Millet and millet based products are known to have lower starch and protein digestibility rates when compared to other cereals. Understanding, why millets are slowly digestible and how they are affected by processing is important in maintaining their lower starch and protein digestibilities when processed.

Scope and approach: This review explores the factors that contribute to the lower starch and protein digestibilities of millets and their underlying mechanisms. The effects of different processing methods on millet starch and protein digestibility rates are also discussed.

Key findings and conclusions: Factors such as starch structural characteristics, starch-protein-lipid interactions, fiber and polyphenols present in millets play significant roles in their hypoglycemic property. The amount and type of fatty acids present in millets significantly affect their starch hydrolysis rates. Unsaturated fatty acids are more effective in reducing starch hydrolysis rates than their saturated counterparts. In-vitro protein digestibility (IVPD) of millets appears to be mostly affected by polyphenols and processing. Simple processing steps such as decortication, germination and fermentation which are mostly applied to millets significantly affect both starch digestibility and IVPD of millets. The adoption of processes that maintain low starch hydrolysis rates and increases protein digestibility in millets should be encouraged.

1. Introduction

The hardy nature of millets, their inherent biodiversity and the relatively lower agricultural inputs needed for their cultivation make millet a crop of choice for many farmers in India, Africa and China. In areas where they are cultivated, millets provide the much-needed energy and to some extent the protein requirements of these populations. With the first reports of the cultivation of millets dating back to about 5550 BCE (Crawford, 2006), millets arguably are the first grains cultivated by man. In terms of production, India is the world's foremost producer of millets in the world, followed by China. Per the Food and Agriculture Organization (FAO) of the United Nations, in 2014, 12.49, 0.31, 14.83, and 0.79 million tons of millet were produced in Africa, the Americas, Asia and Europe respectively (Faostat, 2016). Pearl millet (*Pennisetum glaucum*), foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*) and finger millet (*Eleusine coracana*) are the major species. Fig. 1 shows pictures of some millet types. These different types of millets are cultivated in different parts of the world. While China cultivates mainly foxtail millets, pearl millets are cultivated in India, Nepal and Africa (Obilana, 2003). Proso millets on the other hand are mainly cultivated in North America (FAO, 1995). Nutritionally, millets contain as much as 60–70% dietary carbohydrates, 6–19% protein, 1.5–5% fat, 12–20% dietary fiber, 2–4% minerals, and several phytochemicals (Hadimani, Ali, & Malleshi, 1995). The nutritional quality and potential health benefits of millet have been extensively reviewed by Saleh, Zhang, Chen, and Shen (2013). Apart from the fact that millets do not contain gluten, making them suitable for people with coeliac disease, millets can also be exploited in the management of type II diabetes due to their hypoglycemic property, as reported by several studies on millets and

* Corresponding author.
E-mail address: gannor@umn.edu (G.A. Annor).

http://dx.doi.org/10.1016/j.tifs.2017.05.012
0924-2244/

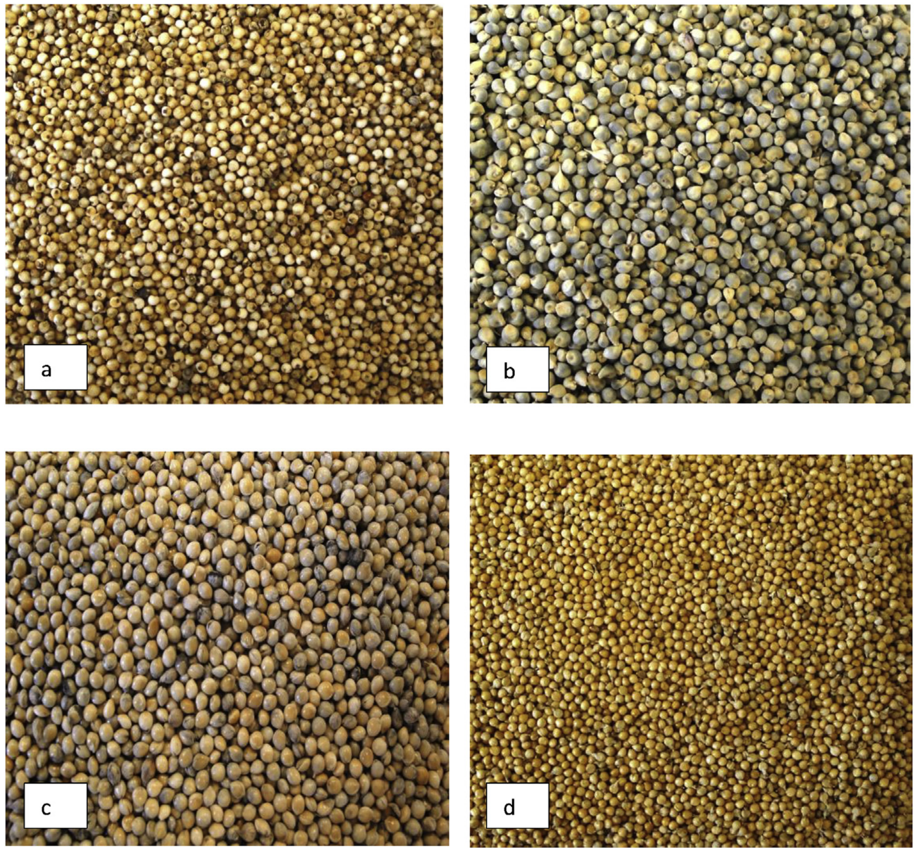

Fig. 1. Different millet types (a: Finger millet, b: Pearl millet, c: Proso millet, d: Foxtail millet).

millet based foods (Anju & Sarita, 2010; Geetha & Easwaran, 1990; Ren et al., 2016; Shukla & Srivastava, 2014; Ugare, Chimmad, Naik, Bharati, & Itagi, 2014). The other side of the coin is protein digestibility, which is lower in millets compared to many other grains (Mertz et al., 1984). This is particularly concerning given the fact that millet forms the basis for staple foods in many developing countries, which would make it one of the primary protein sources. In addition, processing methods that involve hydrothermal treatments may lower the protein digestibility of certain millet types (Gulati et al., 2017).

Understanding the factors that contribute to millets' hypoglycemic property and protein digestibility is important, as it will allow for the development and processing of healthier millet-based food products. This paper consists of three sections. The first discusses the factors that contribute or may contribute the hypoglycemic property of millet and millet-based products. In the second part, in vitro protein digestibility (IVPD) will be discussed. The final part will review the role of treatments/processes for improving and maintaining the nutritional benefits of millets in terms of starch and protein digestibility.

2. Hypoglycemic property of millet

One of the early accounts on the hypoglycemic property of millet can be traced to 1957 when Ramanathan and Gopalak fed finger millet and four other cereals to six normal men between the ages of 25–40 years and a man and woman who had glycosuria. They reported a significantly lower increase in blood glucose of the individuals fed with finger millet when compared to the cereals. Interestingly, they also reported that starch from rice and finger millet fed to these individuals gave increases in blood glucose levels that were similar. This study thus showed that the characteristics of millet starch on its own may not be a factor contributing to the hypoglycemic property of millets but in the presence of lipids, proteins and phenolic compounds may be the contributing factors. Pathak, Grover, Priyali (2000) fed five normal females between the ages of 22–25 year and five non-insulin-dependent diabetes males between the ages of 57–70 years with Indian traditional snacks made from foxtail millet, barnyard millet, legumes and fenugreek seeds and observed significantly lower blood glucose levels compared to when subjects were administered with glucose. The snacks used were Dhokla (55% foxtail millet and barnyard millet, 35% legumes and 10% fenugreek seeds), Uppuma (60% foxtail and barnyard millet, 20% legumes and 10% fenugreek seeds) and Laddu (50% amaranth and foxtail millet, 25% legumes and 25% fenugreek paste). The lowest glycemic index was observed for uppuma, followed by laddu and then dhokla in both normal and diabetic subjects. Even though this observed trend seems to be consistent with the amount of legumes added, Uppuma, which had the lowest glycemic index, contained the most millet. Shobana, Kumari, Malleshi, and Ali (2007) after administering food formulations prepared from wheat, decorticated finger millet, popped and expanded rice and blended with legumes to five normal male and female subjects between the ages of 25–52 years observed significantly lower rates of digestion of the wheat and millet based food formulations compared to the rice based food formulations. They also reported that the wheat based formulations were digested significantly slower than the formulations made from millet. They attributed this observation to gluten-starch interactions as suggested by Jenkins et al. (1987). The glycemic index of refined wheat noodles incorporated with 30% finger millet was significantly lower (45.1) than refined wheat noodles (62.6). These noodles were fed to