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Review

# Advances in grain sorghum and its co-products as a human health promoting dietary system

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ABSTRACT

Grain sorghum (GS) and its co-products are a rich source of chemically diverse phytochemicals, many of which have been reported to protect against multiple human health conditions or diseases that are currently afflicting western cultures. However, due to rapid urbanization and nutrition transition, these diseases are also increasing in developing worlds, making sorghum an even more relevant food staple for these countries. Research on GS and its co-products thus is also steadily increasing but as potential functional foods or as supplements. For example, studies have demonstrated that both GS lipids and its co-product, dry distiller's grain sorghum were able to promote cardiovascular health by reducing both plasma low-density lipoprotein (LDL) and liver cholesterol levels but at different dosage levels. Grain sorghum phenols have also been shown to inhibit hepatic gluconeogenesis enzymes thereby promoting endogenous insulin sensitivity. As these results represent only a few of the health related studies cited in the literature in response to GS within the past 10 years, this manuscript reviews studies on GS and its co-products as a potential health promoting system reported between 2005 and 2015.



**Contents**



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## 1. Introduction

Grain sorghum (GS) is a dietary staple for approximately 500 + million people in more than 30 countries (Henley, 2010) positioning this commodity as the 5th most valuable cereal crop in the world exceeded only by rice, wheat, corn and barley (Fig. 1). The world-wide consumption of GS is most likely a result of its ability to grow in a variety of eco-agricultural areas, including regions that are dry and arid or that undergo severe temperature fluctuations (Henley, 2010).

The United States is the leading GS producer (~20%) followed by Argentina and Australia (USDA Foreign Agricultural Service, 2015). Production of GS is scattered across the US Great Plains with Kansas, Texas, Oklahoma, Colorado and Arkansas accounting for the highest yields (Fig. 2) (USDA's National Agricultural Statistics Service, 2015). Yet, 70–80% of the US produced GS is exported (USDA-FAS, 2015), while the remaining is used primarily as animal feed or for ethanol production (Wang, Weller, & Hwang, 2005). However, GS consumption as a human food source is slowly but steadily growing in the US and other western cultures due in large part to replace wheat as a gluten free alternative (Taylor, Schober, & Bean, 2006). Additionally, the increasing US Asian population has contributed to the higher GS dietary demands by incorporating GS flour into their snacks, cookies and other ethnic foods (Taylor et al., 2006). Various GS varieties are currently being used as a popping GS. Studies have shown that popping improves nutritional quality by reducing anti-nutrients and by increasing grain protein, carbohydrate digestibility and soluble dietary fiber (Murty, Patil, Parsada Rao, & House, 1982). Most of the pop GS varieties are white, small grained and composed of a medium thick pericarp, hard endosperm with a very low germ to endosperm ratio. Popped GS is superior to popcorn in its tenderness, fewer hulls and economic value (Murty et al., 1982; Thorat, Sathwadar, Kulkarni, Chowdari, & Ingle, 1988). As pre-cooked ready to eat food, popped GS are being used as snack foods and specialty foods, which serve as a base for the designation of a functional food.

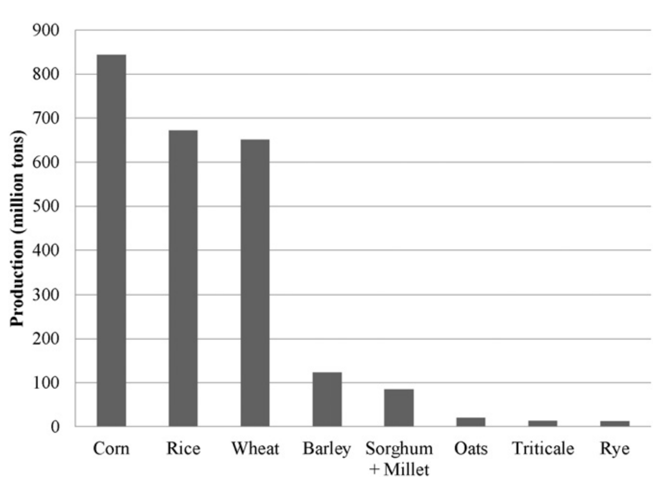


**Fig. 1.** Different types of cereals produced in 2010.
Adapted from Chemistry of cereal grain, p. 12, by P. Koehler, & H. Wieser, 2013, In Gobbetti, M., & Ganzle, M. (Eds.), *Handbook on sourdough biotechnology* (pp. 11–45). New York, NY: Springer.

Additionally, GS has shown to protect against chronic health conditions and diseases that are particularly prevalent in western societies, such as cellular oxidation, inflammation, hypercholesterolemia, cancer, and type 2 diabetes (Shim, Kim, Jang, Ko, & Kim, 2013; Lee et al., 2014; Suganyadevi, Saravanakumar, & Mohandas, 2013; Kim & Park, 2012; Awika & Rooney, 2004). It also must be noted that these health conditions and diseases are becoming more and more common in developing countries because as urban communities grow and as the poor become rich, they adopt diets similar to western cultures. Yet, GS remains widely unrecognized as a multi-faceted human health promoting dietary system for both western and developing countries. Therefore, this manuscript reviews research on the human health benefits of GS and its co-products completed during the past 10 years. As the presence of various types of macro- and micronutrients are responsible for the health promoting properties of GS, an overview of its composition is provided in Section 2. However, these studies may be older than 10 years to provide a suitable point of reference. Subsequent sections focus on in vivo and in vitro studies categorized by condition or disease using either components isolated from GS, GS extracts and its co-products. Each of these sections contain general information on the condition or disease, and at times seminal epidemiology studies or other discoveries that led to more current research on the effects of sorghum on the discussed condition. For related studies reported prior to this time period, the reader is directed to an excellent review provided by Awika and Rooney (2004).

## 2. Composition of GS and its co-products

### 2.1. Basic GS composition

Grain sorghum (*Sorghum bicolor*) is a grain, forage, or cereal crop consisting of either white, yellow, red, brown or black endosperms. Regardless of the different color variations, the main components in each are starch (~75%), protein (~12%), lipids (~4%), fiber (~3%) and ash (~2%) (Hwang, Cuppett, Weller, & Hanna, 2002a). Other nutrients common to all of the varieties include several minerals, vitamins, lipids and amino acid classes, which are listed in Table 1. However, the following discussion focuses on sorghum components that have been specifically targeted for their health benefiting properties, and thus are discussed throughout the remaining sections.