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Review

Nutritive value of wheat and wheat by-products in pig nutrition: A review

P. Rosenfelder, M. Eklund, R. Mosenthin*

Institute of Animal Nutrition, University of Hohenheim, Emil-Wolff-Str. 10, 70599 Stuttgart, Germany

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ABSTRACT

Wheat is an important energy component in diets for pigs which is mainly attributed to its high starch content. The crude protein (CP) content is rather low compared to protein supplements, but due to its high dietary inclusion level wheat provides significant amounts of indispensable amino acids (AA) in diets for pigs. Currently available feed tables on the chemical composition and nutritional value of wheat have in common that they hardly take into account the impact of recent advances in plant breeding including introduction of new cultivars and by-products on the nutritive value of wheat and its by-products. These by-products such as wheat bran, wheat middlings and wheat distillers dried grains with solubles have gained increasing attention in pig nutrition. In particular, processing of wheat for biofuel production resulted in the production of different by-products characterized by relatively high CP and ether extract contents. Moreover, wheat contains various proportions of non-starch polysaccharides (NSP) including arabinoxylans, β-glucans and pectins, which are enriched during processing of wheat to produce flour for human consumption. These components can be used as dietetic components, but they also may interfere with nutrient digestibility. The use of feed enzymes in diets based on wheat and wheat by-products may alleviate the negative effects of NSP on nutrient and energy digestibility, thereby improving the feeding value of these feed ingredients. Accordingly, other processing procedures, such as grinding, extruding, pelleting, micronizing, fermenting and ensiling can improve the nutrient and energy digestibility of wheat in diets for pigs. The object of the present review is to revise the information on the nutritive value of wheat and its by-products in pig nutrition. This revision comprises updated data on the content of AA, energy and carbohydrates in wheat and several wheat by-products including information on standardized ileal protein and AA digestibility.

Contents

Abbreviations: AA, amino acids; ADF, acid detergent fiber; AID, apparent ileal digestibility; ATTD, apparent total tract digestibility; BW, body weight; CP, crude protein; DDGS, distillers dried grains with solubles; DE, digestible energy; DM, dry matter; EE, ether extracts; EU, European Union; GE, gross energy; LMW, low molecular-weight; ME, metabolizable energy; NDF, neutral detergent fiber; NE, net energy; NSP, non-starch polysaccharides; OM, organic matter; SID, standardized ileal digestibility; TID, true ileal digestibility; U, unit; WB, wheat bran; wDDGS, wheat distillers dried grains with solubles; WM, wheat middlings; XU, xylanase activity.

* Corresponding author. Tel.: +49 711 459 23938; fax: +49 711 459 22421.
E-mail address: rainer.mosenthin@uni-hohenheim.de (R. Mosenthin).

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1. Introduction

Wheat is the primary cereal grain produced in the European Union (EU; FAOSTAT, 2012), and bread wheat (*Triticum aestivum*) represents the most important wheat variety worldwide to be used as food ingredient in human nutrition (Matsuo, 1994). In 2009, 33% of the wheat produced within the EU was used as feed (FAOSTAT, 2012) and, in addition, several by-products of wheat processing such as wheat bran (WB), wheat middlings (WM) and wheat distillers dried grains with solubles (wDDGS) are being used in livestock feeding.

Analysis of the chemical composition of wheat reveals considerable differences in contents of nutrients and anti-nutritional factors, mainly due to variations in genetic and environmental factors. Moreover, potential differences in wheat quality can also be expressed by means of physical parameters, such as kernel weight and density (Kim et al., 2005a; McCann et al., 2006).

Wheat can be classified according to seedtime (spring/winter), hardness (soft/hard) and color (white/red). Winter wheat is sown in fall and spring wheat in early spring (Acquaah, 2012). In addition, differences are also being made between hard wheat and soft wheat. In general, soft wheat contains less crude protein (CP) than hard wheat but has higher starch content (Brown, 2010). According to Wiseman (2006), soft wheats are better digestible for non-ruminants than hard wheats due to structural differences in the starch and protein granules. In soft wheats, starch and protein granules are included in a friable matrix, whereas the protein matrix of hard wheats physically entraps starch granules which, in turn, makes it more difficult for digestive enzymes to penetrate into this matrix. The classification based on color refers to the color of the aleurone or outer layer of the wheat kernel (Oleson, 1994). Even more categories for wheat classification are used in the United States. These comprise six classes including hard red winter, hard red spring, soft red winter, durum, soft white and hard white wheat (McFall and Fowler, 2009).

In diets for pigs, wheat is primarily used as an important energy component due to its high starch content ranging from 500 to 800 g/kg dry matter (DM; Lin et al., 1987; Zijlstra et al., 1999; Black, 2001). The CP content averaging 144 g/kg DM (NRC, 1998) is rather low compared to protein ingredients such as soybean meal, but due to its high dietary inclusion level ranging from 300 to 700 g/kg, wheat delivers significant amounts of indispensable amino acids (AA) to the pig. Wheat can supply up to 60% of the animals' requirement for total AA (Myrie et al., 2008) and up to 70% for indispensable AA (Sauer et al., 1981).

Wheat by-products, such as WB and WM are produced when wheat is processed into flour for human consumption (Laurinen et al., 1998; Huang et al., 1999). Moreover, the use of wheat for bio-ethanol production results in the production of various by-products such as wDDGS, wheat wet distillers solubles and condensed distillers solubles (Widyaratne and Zijlstra, 2007a; Pahm et al., 2008b; Pedersen and Lindberg, 2010). By-products of wheat milling are of considerable economic significance as they represent 25% of the original grain (Jondreville et al., 2000). They can reduce feed costs considerably but vary in nutritional value which, in turn, may limit the efficient use of wheat by-products both in poultry and pig nutrition (Slominski et al., 2004). In general WB, WM and wDDGS contain more CP and lysine than the whole kernel (Laurinen et al., 1998; Nyachoti et al., 2005), but these products have higher contents of non-starch polysaccharides (NSP) than the original grain (Slominski et al., 2004), resulting in reduced digestibility of AA and energy (Nortey et al., 2007a).

There exist large amounts of data on the nutritional composition of wheat, however, this review is directed to the evaluation of the nutritional value of spring and winter wheat, as these two types of wheat represent the whole range of values for wheat cultivars.