CHAPTER 1

GENERAL INTRODUCTION AND WORK HYPOTHESIS

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1.1. GENERAL INTRODUCTION

It is generally accepted that feed costs comprise at least 60% of total costs in pork production, with oilseed products and cereal grains representing frequently used components in pig diets. Soybean meal (SBM) as a major by-product of oil extraction from soybeans is the most commonly used protein supplement of plant origin in diets for pigs. Wheat with 76 million tons used for feed production in 2011 is the primarily source of cereals for livestock in Europe (FAOSTAT, 2014). Due to its high starch content (54-75% dry matter (DM); Rosenfelder et al., 2013), wheat is primarily used as energy component in pig diets. The crude protein (CP) content, ranging between 10 and 21% DM (Rosenfelder et al., 2013), is rather low, but due to its high dietary inclusion level (30-70%) wheat can supply up to 60% of the animals' requirement for total amino acids (AA; Myrie et al., 2008). 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 aspects (Rosenfelder et al., 2013). Coefficients of standardized ileal digestibility (SID) of CP and AA in wheat have been published in several feed tables (e.g. AFZ, 2000; NRC, 2012), but there is scarce information on SID values for new wheat genotypes. There is evidence, however, that year of harvest (Canibe and Eggum, 1997) or different environmental conditions may have an impact on digestibility values (Anderson and Bell, 1983).

Wheat is also being increasingly used as base cereal for production of bioethanol due to regulations under public law, which prescribe the use of ethanol-blended gasoline (Nyachoti et al., 2005). Manufacturing of bioethanol results at the same time in production of protein-rich by-products such as condensed distillers solubles and distillers wet grains (Pahm et al., 2008). In most cases, these products are combined and dried, resulting in a by-product referred to as distillers dried grains with solubles (Ganesan et al., 2006). Wet by-products such as wheat wet distillers solubles or wet concentrated distillers solubles (CDS) have been proposed as alternative feed ingredients in diets for monogastric animals including pigs (Pedersen and Lindberg, 2010). However, thermal treatment of these products, used to reduce their water content, may result in a reduction in AA content and digestibility due to occurrence of Maillard reactions, where AA and reducing sugars form AA-sugar complexes (Pahm et al., 2008; González-Vega et al., 2011). Yet, information on the feeding value of wet by-products from bioethanol production derived from wheat is scarce, in particular with respects to SID of AA in wheat CDS.

1.2. Work hypothesis

Based on a comprehensive literature review (Chapter 2), it appears that there is scarce information on SID of AA for currently available wheat genotypes and wet wheat by-products such as CDS in growing pigs. Thus, 2 studies with growing pigs were conducted.

In the first study (Chapter 3), 9 growing pigs with simple T-cannulas at the distal ileum were used to assess the SID of AA in 8 currently available wheat genotypes. The study was part of the "GrainUp" project. This collaborative research project aimed to determine in different livestock species potential variations in feeding value within and between different currently available cereal grains including wheat. The wheat genotypes were grown under same standardized field conditions, and selected as being heterogeneous in their quality grade and protein content.

The second study (Chapter 4) included 2 experiments with growing pigs to assess the protein and energy value of wet CDS, a co-product of the bioethanol production from wheat. In the first experiment, 6 ileally cannulated barrows were used to measure the SID of AA in CDS, whereas in the second experiment contents of digestible, metabolizable, and net energy of CDS were determined with 12 intact pigs.

1.3. References

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CHAPTER 2

NUTRITIVE VALUE OF WHEAT AND WHEAT BY-PRODUCTS IN PIG NUTRITION: A REVIEW

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2. NUTRITIVE VALUE OF WHEAT AND WHEAT BY-PRODUCTS IN PIG NUTRITION: A REVIEW

2.1. SUMMARY

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.

2.2. 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