CHAPTER 1

GENERAL INTRODUCTION AND WORK HYPOTHESIS

1. General introduction and work hypothesis

1.1. General introduction

In the European Union the production quantity of oilseeds (e.g. soybean (SB) and rapeseed (RS)) and their protein-rich by-products increase due to the ban of meat and bone meal and its by-products in diets for livestock (Commission Regulation, 2001) and furthermore due to an increase of biodiesel processing (Lywood and Pinkney., 2012). In the fiscal year 2014/2015, 296 million tons of oilseed meals (OSM) have been produced worldwide (USDA, 2015). Of the total global production of OSM, soybean meal (SBM) represents 68%, followed by 14% rapeseed meal (RSM), 5% cotton seed meal, 5% sunflower seed meal and 3% palm kernel meal (USDA, 2015). Soybean meal is the major by-product of oil extraction from SB. Due to its great protein content, amino acid (AA) profile (rich in lysine (Lys)), and the high digestibility of AA (Weiß and Schöne, 2008; Evonik Degussa, 2010; NRC, 2012), SBM provides the main protein supplement of plant origin in livestock diets. However, apart from its advantages in protein content and AA profile, the nutritional value of SBM is much lower than expected (Bajpai et al., 2005). This is largely attributed to the presence of anti-nutritional factors (ANF), such as trypsin inhibitors that may reduce the digestion of AA (Goebel and Stein, 2011).

Double zero RS *(Brassica napus* or *Brassica rapa*), which is low in glucosinolate (GSL) and erucic acid, represents the most important oilseed crop of the European Union. In general, the growing conditions in Europe are optimal for RS production. Therefore, RS is commonly included in crop rotations. During the recent decades the primary focus has been on the maximization of the seed quality through its oil content for edible oil and biofuel production. Hence, RS contains approximately 400 g oil/kg (AFZ, 2000). After pre-press solvent extraction, the resulting RSM has an excellent balance of AA, in particular its relatively high content of sulfur-containing AA in comparison to other protein feedstuffs including SBM (Weiß and Schöne, 2008), and is used in all species of livestock as a protein source. Factors that might affect the nutritive value of RSM in non-ruminant species include the concentration of nutrients (energy and protein), the digestibility of AA and the presence of ANF. This is reflected by indigestible fiber fractions, GSL and phenolic compounds which are present in RSM (de Lange et al., 1998). The concentration of nutrients in RSM is mainly affected by its fiber content, which is higher than that of SBM. Rapeseed meal contains 26% less protein than SBM (Evonik Degussa, 2010). Furthermore, the OSM quality is influenced by the genotype, growing conditions such as soil type, soil moisture content, precipitation and several variables during processing including temperature, moisture, pressure, and duration of heat application (Qin et al., 1996; Schumann, 2005). Heat treatment improves the nutritional value of SBM and RSM, as it destroys heat-labile ANF (Goebel and Stein, 2011; Jensen et al., 1995). However, excessive heating may negatively affect digestibility of AA (González-Vega et al., 2011; Newkirk et al., 2003).

Feed costs represent 65 to 70% of the variable costs of pig production and play a major role in determining the profitability of a pig enterprise (Simpson, 2003). Soybean meal is commonly used as a protein supplement in the feed industry. In addition, there are many suitable alternatives meeting the nutritional requirements of pigs, while reducing the cost of the ration. However, RSM is sold at a discount relative to the nutritional value of SBM. Compared to SBM, the energy content of RSM is lower and it contains less digestible AA (NRC, 2012; DLG, 2015). A partial replacement of SBM by RSM is economically reasonable. A significant improvement in the nutritive value of RSM could be realized if the discount of RSM was eliminated, but this would require an understanding of the effect of hydrothermal treatment during processing of RSM on ANF content and AA digestibility.

1.2. WORK HYPOTHESIS

The objective of this thesis was to study the effect of desolventizing/toasting conditions on the nutritional quality of OSM. Processing conditions that promote protein damage needed to be identified; ways of producing a higher quality OSM had to be elaborated; methods of measuring protein quality in the meal had to be established, and the possible relationship between processing conditions, *in vivo* protein quality and the susceptibility to heat damage had to be identified. For that purpose, different SBM and RSM were manufactured in a pilot plant under standardized processing conditions. The effect of varying technological treatments on protein quality and GSL content in RSM are summarized in Chapter 2. Two *in vivo* studies with growing pigs were conducted in which both, SBM and RSM were used as protein source in pig diets. In the first *in vivo* study (Chapter 3), growing pigs, fitted with permanent simple T-cannulas at the distal ileum for collection of ileal digesta, were used to assess the chemical composition and the standardized ileal digestibility (SID) of crude protein (CP) and AA in RSM from German oil mills. The second *in vivo* study (Chapter 4) was carried out to determine the effect of different particle sizes and heat treatments of SBM on SID of CP and AA in growing pigs.

1.3. References

AFZ, Ajinomoto Eurolysine, Aventis Animal Nutrition, INRA, ITCF, 2000. AmiPig, Ileal standardised digestibility of amino acids in feedstuffs for pigs.

Bajpai, S., Sharma, A., Gupta, M.N., 2005. Removal and recovery of antinutritional factors from soybean flour. Food Chem. 89, 497–501.

Commission Regulation (EC) No. 999/2001, 2001. Laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies. Off. J. Eur. Union L 147, 1–40.

de Lange, C.F.M., Gabert, V.M., Gillis, D., Patience, J.F., 1998. Digestible energy contents and apparent ileal amino acid digestibilities in regular or partial mechanically dehulled canola meal samples fed to growing pigs. Can. J. Anim. Sci. 78, 641–648.

DLG (Deutsche Landwirtschafts Gesellschaft), 2015. Datenbank Futtermittel der DLG.

Evonik Degussa, 2010. AMINODat®4.0. Amino acid composition of feedstuffs, 4th rev. ed. Evonik Degussa GmbH, Feed Additives, Hanau, Germany.

Goebel, K.P., Stein, H.H., 2011. Ileal digestibility of amino acids in conventional and low-Kunitz soybean products fed to weanling pigs. Asian-Aust. J. Anim. Sci. 24, 88–95.

González-Vega, J.C., Kim, B.G., Htoo, J.K., Lemme, A., Stein, H.H., 2011. Amino acid digestibility in heated soybean meal fed to growing pigs. J. Anim. Sci. 89, 3617–3625.

Jensen, S.K., Liu, Y.G., Eggum, B.O., 1995. The effect of heat treatment on glucosinolates and nutritional value of rapeseed meal in rats. Anim. Feed Sci. Technol. 53, 17–28.

Lywood, W., Pinkney, J., 2012. An outlook on EU biofuel production and its implications for the animal feed industry. In: Makkar, H.P.S. (Ed.). Biofuel co-products as livestock feed. Food and Agriculture Organization of the United Nations, Rome, 2012, pp. 13–34.

Newkirk, R.W., Classen, H.L., Scott, T.A., Edney, M.J., 2003. The digestibility and content of amino acids in toasted and non-toasted canola meals. Can. J. Anim. Sci. 83, 131–139.

NRC (National Research Council), 2012. Nutrient requirements of swine, 11th rev. ed. National Academies Press, Washington DC, United States.

Qin, G., ter Elst, E.R., Bosch, M.W., van der Poel, A.F.B., 1996. Thermal processing of whole soya beans: Studies on the inactivation of antinutritional factors and effects on ileal digestibility in piglets. Anim. Feed Sci. Technol. 57, 313–324.

Schumann, W., 2005. Untersuchungen zum Glucosinolatgehalt von in Deutschland erzeugten und verarbeiteten Rapssaaten und Rapsfuttermitteln, UFOP-Schriften Heft 27, 1–69.

Simpson, G., 2003. Feeding management - $how me the money. Ontario Ministry of Agriculture, Food and Rural Affairs.

http://www.omafra.gov.on.ca/english/livestock/swine/facts/info_money.htm (Accessed June 26, 2015).

USDA (Unites States Department of Agriculture), 2015. Foreign Agricultural Service. Oilseeds: World Markets and Trade. Report June 2015. https://apps.fas.usda.gov/psdonline/circulars/oilseeds.pdf (Accessed June 26, 2015).

Weiß, J., Schöne, F., 2008. Rapsextraktionsschrot in der Schweinefütterung. UFOP-Praxisinformation. http://www.ufop.de/agrar-info/erzeuger-info/fuetterung/rapsextraktionsschrot-in-der-schweinefuetterung/ (Accessed June 26, 2015).

CHAPTER 2

EFFECT OF THE DESOLVENTIZING/TOASTING PROCESS ON CHEMICAL COMPOSITION AND PROTEIN QUALITY OF RAPESEED MEAL

Rainer Mosenthin[1,*], Ulrike Messerschmidt[1,2], Nadja Sauer[1,3], Patrick Carré[4], Alain Quinsac[5], Friedrich Schöne[6]

*Corresponding author.

[1]University of Hohenheim, Institute of Animal Science, Emil-Wolff-Strasse 10, 70599 Stuttgart, Germany.

[2]Present address: KWS SAAT SE, Grimsehlstrasse 31, 37555 Einbeck, Germany.

[3]Present address: Landwirtschaftliche Untersuchungs- und Forschungsanstalt Speyer, Obere Langgasse 40, 67346 Speyer, Germany.

[4]OLEAD, 11 rue Monge, Parc Industriel, 33600 Pessac, France.

[5]Terres Inovia, 11 rue Monge, Parc Industriel, 33600 Pessac, France.

[6]Thuringian State Institute of Agriculture, Naumburger Strasse 98, 07743 Jena, Germany.

Submitted to Journal of Animal Science and Biotechnology

2. Effect of the desolventizing/toasting process on chemical composition and protein quality of rapeseed meal

2.1. Abstract

Background: During processing in a desolventizer/toaster (DT), rapeseed meal (RSM) is heated to evaporate the hexane and to reduce the level of heat-labile anti-nutritional factors such as glucosinolates (GSL). However, excessive heat treatment may reduce amino acid (AA) content in addition to lower AA digestibility and availability in RSM. The objective of the present study was to produce from one batch of a 00-rapeseed variety (17 µmol GSL/g dry matter (DM), seed grade quality) five differently processed RSM under standardized and defined conditions in a pilot plant, and to determine the impact of these different treatments on protein solubility and chemical composition, in particular with regard to contents of AA including reactive Lys (rLys) and levels of total and individual GSL.

Methods: Four RSM were exposed to wet toasting conditions (WetTC) with increasing residence time in the DT of 48, 64, 76, and 93 min. A blend of these four RSM was further processed, starting with saturated steam processing (< 100 °C) and followed by exposure to dry toasting conditions (DryTC) to further reduce the GSL content in this RSM.

Results: The contents of neutral detergent fiber and neutral detergent fiber bound crude protein (CP) increased linearly ($P < 0.05$), as residence time of RSM in the DT increased from 48 to 93 min, whereas contents of total and most individual GSL and those of Lys, rLys, Cys, and the calculated ratio of Lys:CP and rLys:CP decreased linearly ($P \leq 0.05$). The combination of wet heating and DryTC resulted in the lowest GSL content compared to RSM produced under WetTC, but was associated with lowest protein solubility.

Conclusions: It can be concluded that by increasing residence time in the DT or using alternative processing conditions such as wet heating combined with DryTC, contents of total and individual GSL in RSM can be substantially reduced. Further *in vivo* studies are warranted to elucidate if and to which extent the observed differences in protein quality and GSL content between RSM may affect digestibility and bioavailability of AA in monogastric animals.

2.2. Background

Rapeseed meal (RSM) is a by-product of oil processing and commonly used as a protein source for livestock. Among protein feedstuffs, production of RSM ranks in second place behind soybean meal [1, 2]. Despite its well-balanced amino acid (AA) profile [3], in particular its relatively high content of sulfur AA in comparison to other protein feedstuffs including soybean meal [4, 5], the use of RSM in diets for monogastric animals is often limited due to the presence of several anti-nutritional factors. These include low digestible and indigestible fiber fractions such as neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL; [6, 7]) and different glucosinolates (GSL; [8–10]). Depending on the type and level of GSL in the diet of monogastric animals, negative effects on feed intake and growth performance [8, 11–14], in addition to liver- and thyroid-hypertrophy [15] have been reported.

The transition from so called 0-rapeseed (RS) varieties, characterized by low erucic acid content (< 20 g/kg of total fatty acid content; [16]) but high total GSL content of 50-100 μmol/g seed [15, 11], to 00-RS varieties resulted in considerably lower contents of GSL (< 25 μmol total GSL/g seed; [17]). Consequently, the use of RS products in livestock feeding increased worldwide [18, 16]. For example, the production of RSM in Germany went up from less than two million tons in 2000 to more than four million tons in 2011 [19]. With the introduction of 00-RS varieties, the content of total GSL in solvent extracted and toasted RSM decreased from 150 μmol total GSL/g dry matter (DM) in 0-RSM to levels ranging between 1-22 μmol total GSL/g DM in 00-RSM [20]. Nowadays, the content of total GSL in RSM produced in Germany from commercially available 00-RS varieties averages 8.8 μmol total GSL/g RSM [21].

As GSL are known to be heat-labile, thermal treatment during processing of RS, especially during the desolventizing/toasting process, reduces their contents in RSM substantially [3]. Thermal processing of oilseed meals in the desolventizer/toaster (DT) is primarily used to remove the hexane needed for oil extraction. Temperature, steam pressure, and duration of heat treatment during processing are considered to be the main factors responsible for reduction of GSL in RSM [22]. Excessive heat treatment, however, may result in the degradation of AA, thus reducing protein quality of RSM [23]. Therefore, there is a need for optimizing the processing conditions during the desolventizing/toasting process by maximizing removal of GSL in RSM, but without reducing protein solubility, AA contents, and AA digestibility and bioavailability [3, 24, 25].

There are several reports describing the effect of heat treatment, in part under wet conditions, on the degradation of GSL in RSM (*e.g.* [4, 3, 26]). However, no study has been published so far, in which the combined effect of different processing conditions (*e.g.* steam pressure, temperature, residence time in the DT) during manufacturing of RSM on their