Bulgarian Journal of Agricultural Science, 28 (No 3) 2022, 510–515

Influence of different inclusion levels of wheat dried distiller's grains with soluble (DDGS) in the diet of growing pigs on the digestibility of nutrients

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Abstract

Ganchev, G., Ilchev, A. & Nedelkov, K. (2022). Influence of different inclusion levels of wheat dried distiller's grains with soluble (DDGS) in the diet of growing pigs on the digestibility of nutrients. *Bulg. J. Agric. Sci., 28 (3)*, 510–515

The objective of this study was to determine the total tract digestibility coefficients of growing pigs fed diets with different inclusion levels of wheat dried distillers grains with soluble (wDDGS) produced in Bulgaria. Four castrated male pigs from the Danube White breed with an average body weight of 34 ± 0.82 kg, housed in individual metabolic cages, were used in the digestibility experiment. Four different diets were examined: 1) a basal diet (100 wheat), consisting mainly of wheat (96.7% wheat and 3.3% vitamins and minerals); 2) 60/40 DDGS diet, in which DDGS was included at 40%; 3) 40/60 DDGS diet, in which DDGS was included at 60%, and 4) DDGS based diet (100 DDGS), consisting mainly of wheat DDGS (97.85% DDGS and 2.15% vitamins and minerals). The apparent total tract digestibility coefficients of dry matter (DM), crude protein (CP), ether extract (EE), crude fibers (CF), and nitrogen-free extracts (NFE) were determined. By increasing wheat DDGS in the rations of growing pigs, a significant reduction in digestibility coefficients of the main nutrients (CP, EE, CF, and NFE) was observed.

Keywords: wheat; wheat DDGS; digestibility; growing pigs
Abbreviations: CF – crude fiber; CP – crude protein; EE – ether extract; NFE – nitrogen free extract

Introduction

Wheat DDGS obtained from ethanol production has a 10-20% higher gross energy (GE) content, and approximately 3 times more protein, fat and fiber compared to the wheat grain (Nyachoti et al., 2005; Widyaratne & Zijlstra, 2007; Stein & Shurson, 2009; Cozannet et al., 2010a; Liu, 2011; Rosenfelder et al., 2013; Pedersen et al., 2014). This identifies wheat DDGS as a suitable alternative source of energy and protein in pig rations (Avelar et al., 2010; Zijlstra & Beltranena, 2013; Woyengoet al., 2014). However, the higher content of CF limits its use due to the negative impact they have on the digestibility of energy and protein (Thacker, 2006; Avelar et al., 2010; Jarret et al., 2011; Gutierrez et al., 2016). The digestibility of most of the amino acids in DDGS is lower than the digestibility in the grain from which it is usually produced, which is due not only to the higher level of crude fiber in DDGS, but in many cases to heat damage during its production (Pahm et al., 2008; Stein & Shurson, 2009; Almeida, et al., 2013). The greatest variation in the digestibility of amino acids was found in lysine (Fastinger & Mahan, 2006; Cozannet et al., 2010; Rosenfelder et al., 2013). In addition, several studies have shown very wide variations in both the chemical composition and digestibility of nutrients in different batches of DDGS from the same raw material (Pahm et al., 2008; Liu, 2011; Liu & Rosentrater,

2012; Anderson et al., 2012; Li et al., 2015; Agyekum et al., 2016; Li et al., 2016; Wang et al, 2016). Studies on the use of different amounts of wheat DDGS in pig rations are also controversial. In some of these experiments it was found that the use of 10% (Woyengo et al., 2016), up to 30% (Curry et al., 2019) and even 60% DDGS in rations (Weber et al., 2013) had no effect on growth performance indicators. In others, the inclusion of 0%, 5%, 10%, 15% or 20% wheat DDGS in the rations of weaned pigs linearly reduced average daily gain (ADG) and feed efficiency (Wang et al., 2016) and average daily feed intake – ADFI (Avelar et al., 2010; Thacker, 2012). Decreases in ADG and ADFI have also been found with the inclusion of up to 30% wheat DDGS in the rations of growing pigs (Thacker, 2006; Wu et al., 2016) or growing-finishing pigs (Widyaratne & Zijlstra, 2007).

The available data do not allow definitive conclusions to be drawn about the impact of the inclusion of different amounts of wheat DDGS in the rations of growing pigs. The aim of the present study was to investigate the effect of wheat DDGS levels in the ration of growing pigs on feed consumption and nutrient digestibility.

Materials and Methods

The animal experiment was conducted in the Swine Research Center at the Faculty of Agriculture, Trakia University. Four castrated male pigs from the Danube White breed with initial body weight of 34 ± 0.82 kg, housed in individual metabolic cages, were used in four consecutive the digestibility experiment. Each experiment included a 5-day preliminary/adaptation and a 5-day trial period during which feces were collected. Four different diets were examined: 1) a basal diet (100 wheat), consisting mainly of wheat, (96.7% wheat and 3.3% vitamins and minerals); 2) 60/40 DDGS diet, in which DDGS was included at 40%; 3) 40/60 DDGS diet, in which DDGS was included at 60%, and 4) DDGS based diet (100 DDGS), consisting mainly of wheat DDGS (97.85% DDGS and 2.15% vitamins and minerals). Diets were formulated using wheat, wheat DDGS, limestone and other vitamin/mineral supplements (Table 1) to meet or exceed the nutrient requirements for growing pigs (based on NRC, 2012). The chemical composition of the feed used is shown in Table. 2.

During the adaptation periods, the animals were fed *ad libitum* in order to specify the consumption. After completion, the required amount of feed was weighed for each day of the trial periods. The pigs had free access to fresh potable water and were fed twice daily at 0830 h and 1630 h. The refusals

Table 2. Chemical composition of diets fed to growing pigs (g/kg DM)

Items	DM	CP	EE	CF	NFE
100 Wheat	898.7	124	21	25	811
60/40 DDGS	902	181.2	36.2	46.6	699.4
40/60 DDGS	903.7	209.8	43.8	57.4	643.6
Wheat DDGS	907	267	59	79	532

Table 1. Composition and nutritional value of dietary treatments (% or as indicated)

Items	Diets			
	1	2	3	4
	100 Wheat	60/40 DDGS	40/60 DDGS	100 DDGS
Wheat, %	96.7	57.25	37.54	-
DDGS, %	-	40	60	97.85
Limestone, %	1,4	1,15	1	0,8
Dicalcium phosphate, %	1,1	1	0.96	0.85
Salt, %	0.3	0.1	-	-
Vitamin premix, %	0.5	0,5	0.5	0.5
1 kg compound feed contains				
DE, MJ/kg	14,1	13,3	12,9	12,1
CP, %	10,8	16	18,7	23,7
CF, %	1,8	4	5	7
Ca, %	0.81	0.81	0.81	0.82
P available, %	0.32	0.32	0.32	0.32
Digestble amino acids, %				
Lysine	0.32	0.38	0.41	0.47
Methionine+Cystin	0.45	0.6	0.67	0.8
Threonine	0.33	0.52	0.62	0.79
Tryptophan	0.13	0.23	0.27	0.36

were collected each morning before feeding and stored in individual plastic bags.

Fecal collection during the trial period was carried out in the morning before feeding the animals. A sample of 10% of the total amount was taken for analysis daily after homogenization. Fecal samples were oven dried at 65°C for 48 h, ground through a 1-mm sieve in a Wiley mill (Thomas Scientific), homogenized and saved in sealed plastic bags for further analyses.

All dried samples were analyzed by wet chemistry methods for CP (method 990.03; AOAC International, 2000), ether extract (EE, method 2003.05; AOAC, 2006), crude fiber (method 962.09; AOAC) and minerals (method 985.01; AOAC, 2000) (Table 1).

The apparent total tract digestibility was calculated as a difference of consumed nutrients and nutrients excreted with feces.

Data were analyzed for the fixed effect of different DDGS levels using STATISTICA 10 for Windows (2010). Significance was declared at $P < 0.05$.

Results and Discussion

In the fermentation process, during ethanol production, roughly 60-70% of the starch in the grain is converted into ethanol and carbon dioxide (Woyengo et al., 2016). The by-products after production have approximately three times higher content of crude protein, crude fat, and crude fiber (Nyachoti et al., 2005; Widyaratne & Zijlstra, 2007; Stein & Shurson, 2009; Liu, 2011; Rosenfelder et al., 2013; Pedersen et al., 2014) from raw materials. This composition defines DDGS as a good source of protein and fat in pig rations. However, the higher content of CF in DDGS has a negative effect on the digestibility of energy and protein and limits its use in pig rations (Thacker, 2006; Avelar et al., 2010; Jarret et al., 2011; Gutierrez et al., 2016). The high fiber content of DDGS is also associated with reduced feed consumption and increased fecal excretion.

Table 3 shows the food and water consumption data and the amount of feces excreted. The highest feed consumption was found when the wheat grain was fed alone – about 21% compared to the diets containing DDGS. Increasing the amount of DDGS up to 40 and 60% resulted in reducing consumption by 11 and 12%, respectively. The higher amount of crude fiber in DDGS rations is probably the main reason for the reduced consumption because it is known that the high fiber content may limit the physical ability of the intestines to digest more food (Wu et al., 2016). An increase in the amount of DDGS may also cause a change in the taste or smell of the ration leading to a decrease in consumption (Nyachoti et al., 2004). A similar decrease in consumption has been found in a number of other studies (Thacker, 2006; Widyaratne & Zijlstra, 2007; Avelar et al., 2010; Thacker, 2012; Wu et al., 2016). Curry et al. (2019), however, did not observe any effect on feed intake by increasing the level of DDGS in the rations of growing pigs.

The results of our study show that increasing the amount of DDGS in the rations significantly increases the amount of feces excreted. This increase is 42 and 56% for the 40 and 60% DDGS rations, respectively, compared to the wheat-based ration. In the case of DDGS-based ration, the amount of feces is 69% higher than the diet containing only wheat. The increase in the total fecal mass observed in animals fed the fiber rich diet could be attributed also to the greater ability of excreta to retain water from fiber, and to the excretion of other undigested products together with fibers (Egron et al., 1996). After fermentation during the bioethanol production process, products with a higher content of difficult-to-ferment fiber remain (Jha et al., 2015). When used in pig rations, these products led to a decrease in DM digestibility, as well as an increase in the amount of feces excreted (Widyaratne & Zijlstra, 2007; Pedersen & Lindberg, 2010; Urriola et al., 2010; Jarret et al. 2011; Jarret et al. 2012; Thacker, 2012).

The digestibility of nutrients is shown in Table 4. The data indicate that as the amount of DDGS in the rations increases, the digestibility coefficients of the nutrients decrease. The decrease in digestibility with increasing DDGS is probably due to the increased crude fiber level in the ration. Higher dietary levels of insoluble fiber lead to an increase of the

Table 3. Feed intake and amounts of excreted fecal

Items	Diets			
	1	2	3	4
	100 Wheat	60/40 DDGS	40/60 DDGS	100 DDGS
Intake feed, g/day	892.50 ± 30.12^{a}	793.75 ± 26.15^{b}	784.38 ± 23.82^{c}	738.75 ± 31.82^{d}
Intake DM, g/day	802.11 ± 27.07^{a}	715.99 ± 23.59^{b}	708.83 ± 21.53^{b}	670.05 ± 28.86^{c}
Fecal, g/day	422.5 ± 38.82^{a}	601.25 ± 40.86^{b}	657.5 ± 34.54^{c}	713.13 ± 38.26^{d}
Fecal DM, g/day	118.3 ± 10.11^{a}	160.97 ± 11.00^{b}	193.00 ± 11.85^{c}	226.48 ± 7.88^{d}

Note: a, b, c, d – Means within a row lacking a common superscript differ significantly at $P < 0.05$

Table 4. Apparent total tract digestibility coefficients

Items	Diets			
	1	2	3	4
	100 Wheat	60/40 DDGS	40/60 DDGS	100 DDGS
DM	85.27 ± 0.92[a]	77.01 ± 2.06[b]	72.92 ± 1.00[c]	66.16 ± 1.57[d]
CP	79.87 ± 2.74[a]	67.17 ± 2.15[b]	62.49 ± 2.10[c]	59.92 ± 1.07[c]
EE	69.55 ± 2.04[a]	63.26 ± 2.63[b]	65.90 ± 1.13[b]	75.58 ± 1.65[c]
CF	31.82 ± 2.58[a]	27.1 ± 0.78[b]	25.03 ± 0.43[bc]	23.03 ± 0.99[c]
NFE	91.60 ± 0.92[a]	87. 92 ± 1.7[a]	85.88 ± 0.79[ab]	79.95 ± 2.71[b]

Note: a, b, c, d – Means within a row lacking a common superscript differ significantly at $P < 0.05$

passage rate through the gastrointestinal tract (GIT), possibly due to physical stimulation of the walls of the GIT by the insoluble fiber. Microorganisms acting on these fibers in the small intestine may, therefore, cause a reduction in diet digestibility, by the creation of a physical barrier to the action of certain digestive enzymes (Silva, 2015).

The difference in the digestibility of DM is about 22% for self-fed raw materials (wheat and DDGS). When increasing the amount of DDGS in the ration of 40 and 60%, the digestibility of DM decreases by 10 and 15%, respectively (Table 4). A decrease in the digestibility of CF as a result of an increase in DDGS in rations was also found in other studies by Nyachoti et al. (2005), Avelar et al. (2010), Pedersen et al. (2010), Jarret et al. (2011), Jarret et al. (2012), Agyekum et al. (2016), Acosta et al. (2020).

The high protein content of DDGS identifies it as a suitable alternative source of protein. However, the effectiveness of using DDGS in pig rations depends on the digestibility of the protein, which is largely determined by its high fiber content. Wheat DDGS is rich in arabinoxylans, cellulose and lignin (Rosenfelder et al., 2013; Pedersen et al., 2014). By the addition of fibrous feedstuffs in pig diets, improved microbial activity in the gut and increased incorporation of N from the diet into bacterial biomass were observed (Noblet & Le Goff, 2001). Additionally, wheat DDGS may also contain up to 25% non-protein N (from CP) which in turn may increase fecal N output (Widyaratne & Zijlstra, 2007). We found that increasing the amount of DDGS up to 40% in the ration reduced the CP digestibility by 16%. However, with the inclusion of 60% DDGS, the CP digestibility decreased by 22%. Nyachoti et al. (2005), Widyaratne & Zijlstra, (2007), Jarret et al. (2011), Jarret et al. (2012), Wang et al. (2016), Acosta et al., (2020) also reported a decrease in CP digestibility with the inclusion of wheat DDGS in pig rations. The lower digestibility of CP can also be explained by increased endogenous secretion, decreased hydrolysis, and absorption of nutrients, or by both (Wilfart et al., 2007). Our results showed a 25% lower digestibility of wDDGS CP compared to wheat.

Wheat DDGS has a relatively high fat content – between 4-6% on a DM basis, which determines its higher energy value. However, the digestibility of ether extract decreases with an increasing amount of DDGS in the ration, and the results of experiments showed that the digestibility of fat in rations by 40% and 60% DDGS is about 9% and 5% lower compared to the wheat-based ration, respectively. Corassa et al. (2019) also found a decrease in the digestibility of EE with an increase in the amount of DDGS in the ration of 20 and 40% but did not find differences in the digestibility of EE between rations containing 40 and 60% DDGS (Corassa et al., 2017). Acosta et al. (2020) also found that the level of DDGS in the ration did not affect the digestibility of EE. By using 100% DDGS in the ration, we observed an increase in the digestibility of EE compared to the other three types of rations. This is most likely due to the higher level of fat in this ration. The digestibility of crude fats is improved with increasing EE in the ration (Kil et al., 2010) and fat content in DDGS (Graham et al., 2014).

The high fiber content of DDGS led to a reduction of the fiber digestibility at the whole digestive tract, which in turn has also affected the nutrient digestibility (Urriola & Stein, 2010). The fibers in DDGS are mainly insoluble due to the high content of insoluble arabinoxylans, cellulose and lignin (Rosenfelder et al., 2013; Pedersen et al., 2014) and are resistant to fermentation in the colon (Urriola & Stein, 2010; Urriola et al., 2010; Jha et al., 2015). Less than 50% of the total amount of fiber in DDGS remains unfermented after passage through the GIT of pigs (Urriola et al., 2010). It was also found that only 18% of NDF fermentation occurs in the large intestine (Gutierrez et al., 2014). Due to the higher fiber content of DDGS, an increase in its dietary inclusion level would lead to an increase of fibers in the diet, as well as to decreased fiber digestibility. This was confirmed by the results of Corassa et al. (2017), Corassa et al. (2019), Acosta et al. (2020), who reported a reduction in the digestibility of fibers in rations with different levels of DDGS. The data on the digestibility of CF in our study followed the same trend. The coefficient of digestibility of CF of wheat-based

diet was 31.82%. The inclusion of 40% DDGS in the ration resulted in a reduction of the CF digestibility up to 27.1%, and 60% DDGS diet up to 25.03%. The digestibility of CF was 23.03% at the ration containing 100% DDGS.

There are significant differences in coefficient of digestibility for NFE. The digestibility of NFE of wheat was relatively high and reached 91.60%. The inclusion of 40% DDGS reduced digestibility by 4%, while a 60% DDGS diet by 6%, respectively. This decrease in the digestibility of NFE is likely because of the higher amount of CF in the ration.

Conclusion

The expanding inclusion of wheat DDGS in the diets of Danube White growing pigs resulted in a reduction of the feed consumption and also increased the amount of feces excreted. The higher inclusion level of wheat DDGS in the rations of growing pigs reduced the digestibility coefficients of the main nutrients – CP, EE, CF and NFE.

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Received: **April 19, 2021**, *Accepted*: **May 10, 2022,** *Published*: **June, 2022.**