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Including Hydrolyzed wheat proteins in starter feed diets for piglets: an excellent protein source in combination with blood plasma.

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Animal nutritionists are constantly looking for alternative protein sources for starter feed. Fishmeal, as an example, is recognized as a good quality protein source, however, fishmeal is used less and less because of decreasing availability of supply and increased pricing volatility. Since young piglets have immature digestive and immune systems, a high quality protein source is an absolute requirement. Selecting a protein source to meet the nutritional needs of the pig must also be balanced with economics. Proteins that are more stable in terms of price are often preferred over ingredients that tend to experience more market volatility.

Hydrolysed wheat protein (HWP) is a soluble protein source produced from vital wheat gluten. The raw material undergoes a specific hydrolyzation process with a food-grade enzyme, which then goes through a purification step before it is dried. The protein is highly concentrated and digestible with around 80% crude protein on a product basis. The finished product also contains 6% fat, 3% starch and less than 1% fiber. The lack of anti-nutritional factors from wheat protein gives it versatility for use in formulation of diets for a variety of different animal species. These characteristics also make HWP an ideal candidate to be included in starter feed diets. In particular when HWP is used in combination with blood plasma, which is considered an excellent protein source, but is often more expensive than other readily available protein sources. When HWP is used in combination with plasma there is often times a synergistic effect that is created in terms of performance, but the combination also helps improve diet economics as well. This paper focuses on HWP properties and on the results obtained when blending HWP and plasma on gut health and growth from a metabolic perspective.

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Hydrolyzed wheat proteins have similar or even better protein digestibility than animal proteins.

Weaning is often associated with gut damage. There is a period of transient villous atrophy and crypt hyperplasia after weaning, probably due to anorexia. Protein may increase this phenomena: a correlation between anorexia, crypt hypertrophy, and local inflammatory responses has been observed when piglets are fed with a diet based on soybean meal compared with those fed a milk replacer (Heo et al., 2012). Additionally, piglets are predisposed to post-weaning diarrhea (**PWD**). PWD is associated with a dysbiosis in the intestine due to the greater proliferation of proteolytic and potentially pathogenic bacteria. Fermentation of protein substrates in the large intestine produces potentially toxic compounds such as ammonia and amines, which have been implicated to PWD. Furthermore, these bacteria may produce enterotoxins and their adhesion to the intestinal epithelium results in activation of guanosine and adenosine monophosphate systems and in increasing secretion of sodium, chloride, hydrogen carbonate ions into the lumen while decreasing the absorption of liquids and salts (Heo et al., 2012). That leads to hyper-secretion of liquids and salts that exceeds the water capacity of colon. Both sources and levels of protein may influence enteric health in piglets. A strategy to decrease the risk of PWD is by using a highly digestible protein source in order to minimize the part of undigested proteins reaching the large intestine to be fermented by bacteria.

The crude protein digestibility of HWP is comparable to the digestibility of blood plasma. Indeed, no significant differences on apparent digestibility of dry matter, organic matter, and crude protein are observed when 8% spray-dried porcine plasma are replaced by 8% HWP (Solpro®, manufactured by Tereos, France) in diets of 21-day old piglets for a 28-day period (Lai et al., 2004). Apparent and standardized ileal digestibility (**AID** and **SID**) has been determined in a trial using 10 weaned piglets (BW: 9.2 kg) fitted with T-canula at the distal ileum (South Dakota, US; Tereos unpublished data). Piglets received a N-free diet and a diet based on either spray dried porcine plasma or HWP (Solpro®, manufactured by Tereos, France). HWP resulted in significant higher apparent and standardized ileal digestibility (AID: 79.8 and 88.2%; SID: 88.6 and 96.5% respectively for plasma and HWP). Additionally, substituting 10% of high quality LT herring meal with 9.5% HWP in diets of weaned piglets (28 days of age) significantly increases apparent digestibility of dry matter, organic matter, and crude protein calculated from 0 to 2 weeks after weaning and significantly increases apparent digestibility of crude protein calculated from 3 to 5 weeks after weaning (Blasco et al., 2005). Using HWP has been shown to improve N utilisation in the small intestine compared to fishmeal. The digestive contents of pigs fed HWP when compared to pigs fed fishmeal shows a much lower ammonia-N concentration (Blasco et al., 2005), indicating a lower microbial deamination and hence increased amino-acid availability in the small intestine. The high digestibility of HWP is certainly related to its low fiber content and the absence of antinutritional factors.

Hydrolyzed wheat proteins present a high content in sulfur amino acids and are rich in glutamine, a functional amino-acid that may be important to maintain gut health.

HWP and plasma may be complementary in terms of amino-acid profile. While HWP is rather low in lysine, it contains higher levels of the sulfur-containing amino acids than plasma, due to the numerous di-sulfur bounds (methionine + cysteine, around 4.6 g/100 g proteins); while plant protein sources are generally low in sulfur-containing amino acids. As an example, soybean meal and soy protein concentrate respectively contain 2.7 and 2.9% Crude Protein of methionine plus cysteine (Table 1).

Furthermore, HWP has a much higher content of the amino-acid glutamine (around 10% for plasma versus 30% as fed basis for plasma and HWP; Table 1). Glutamine is a major substrate for all rapidly proliferating cells and plays an important role in maintaining intestinal trophicity. Besides these effects on gut morphology, glutamine also constitutes a major substrate for immune cells, thus modulating immune response. Several studies have demonstrated that free glutamine exerts positive effects on gut morphology and on immune system in non-infected and infected piglets (Table 2). Using HWP in a starter diet can therefore be used as part of a strategy to help maintain intestinal health and in turn improve growth performance levels.

Several studies evaluated the potential of HWP for a partial replacement of different proteins on gut morphology. No reduction of villous height is observed when compared to animal proteins, and notably fishmeal (Blasco et al., 2005). Similar results are reported when 8% spray dried porcine plasma are replaced with 8% HWP (Lai et al., 2004). Significant increases of villous height and digestive enzyme activities are observed in broilers and fish when HWP partly replaces soy proteins in the diet (Van Leeuwen et al., 2004; Qiyou et al., 2011). Beside effects on gut structure and activity, a modulation of immune or anti-oxidative system is observed in rats and fish (Yang et al., 2004; Zhu et al., 2011; Voller et al. 2015). Feeding rats with HWP increased the secreted IgA's in the intestinal contents and the phagocytic activity of peritoneal macrophages while it improved the anti-oxidative system in juvenile hybrid sturgeon and in rainbow trout. These studies reinforce the potential of HWP as protein source that may help maintain gut health just after weaning of piglet.

Hydrolyzed wheat proteins result in maintaining high growth performance levels for weaned piglets and an association with blood plasma even results in improving diarrhea incidence and in decreasing blood urea nitrogen content.

Spray-dried plasma is usually considered to be an essential ingredient in the diet of early weaned pigs. Plasma has been demonstrated to reduce inflammation (Jiang et al., 2000), improve immunity (van Dijk et al., 2001) and feed efficiency (Bosi et al., 2004); and decrease PWD (Newbold et al., 2007). The high digestibility and the interesting essential amino-acid profile and the presence of functional biological components in plasma undoubtedly helps explain why this protein source is largely kept in piglet diets in spite of its elevated price. HWP may be used in combination or in partial replacement of plasma as a synergistic effect has been highlighted.

Plasma and HWP are complementary ingredients because of their amino-acid profiles and because of their potential effects on improving gut health. A blend of these 2 protein sources provides an interesting formulation option which helps decrease the inclusion rate of plasma to achieve improved diet economics A study evaluating a blend of 4% spray-dried porcine plasma and 4% HWP resulted in similar digestibility and growth performance of weaned piglets than those of piglets fed with a plasma control diet (Lai et al., 2004). Furthermore, using HWP did not increase incidence of diarrhea in weaned piglets. The lowest diarrhea index in this study was obtained with piglets fed 4% spray-dried porcine plasma plus 4% HWP (Figure 1). Similarly, the lowest blood urea nitrogen level was obtained for this same blend. This particular parameter is considered to be negatively correlated with N deposition. The authors concluded that "plasma can be partially replaced by Solpro500 without any negative effect on performance, fecal digestibility of nutrients and intestinal morphology in early-weaned pigs. Moreover, Solpro500 has a positive effect on preventing diarrhea in weaned pigs."

Conclusion and implications

Hydrolyzed wheat protein is a highly digestible protein source containing elevated levels of the sulfur containing amino acids, methionine and cysteine. HWP is also rich in glutamine, an amino-acid that has strong functional properties. Due to its high digestibility and the high level of glutamine, HWP becomes an interesting protein source that can be used in starter feeds for piglets which are predisposed to gut troubles, especially PWD. Several studies evaluating the use of HWP in piglets and in other species demonstrate the encouraging effects that HWP can potentially have on gut health and the immune system. Furthermore, several studies have been conducted with HWP in piglets to measure growth performance levels when used as a total replacement for fishmeal and as a partial replacement of plasma and/or skimmed milk. The results from this work often show no significant differences in performance and even suggest that a blend of plasma and HWP can be used to help reduce the incidence of diarrhea.

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Table 1- Relative percentage of Crude Protein (CP), methionine + cysteine and glutamine in various protein sources.

Protein source	CP, % product	Met +Cys, % CP	Glutamine, %CP
Hydrolysed wheat protein (Solpro®)	**80**	**4.6**	**40.0**
Soy protein concentrate	64	2.7	19.0
Potato protein concentrate	78	3.6	10.6
Soy bean meal	48	2.9	17.8
Porcine plasma	78	4.0	12.8
Fish meal	70	3.7	12.9

Table 2- Synthesis of studies conducted in pigs evaluating effects of glutamine (Gln) on growth performance, gut health, and immunity.

Age, d	Period, day	Treatments	Effects of Gln	Reference
21	14	0, 0.2, 0.6 and 1% Gln	- Prevention of jejunal atrophy - Increased gain:feed ratio (+ 25%)	Wu et al., 1996
21	7	Control +/- *E. coli* +/- 4% Gln	In infected pigs - Higher intramuscular Gln - Higher white blood cell counts - Stimulated antibiotic response	Yoo et al., 1997
28	14	0 and 1% Gln	- Prevention of jejunal atrophy - Improvement of absorption capacity of small intestine	Liu et al., 2001
17	3	Control+/- *E. coli* +/- 2% Gln	- Alleviating growth depression due to *E. coli* challenge - Maintaining intestinal morphology and function	Yi et al., 2005
21	20	0 vs 1% Gln	- 10 day: decreased Feed Conversion Ratio; 20 day: increased Average Daily Gain - Increased growth hormone concentration in blood	Zou et al., 2006
21	7	1% L-alanine vs 1% L-Gln	- Increased expression of genes for cell growth and removal of oxidants with Gln - Reduced expression of genes for oxidative stress and immune activation	Wang et al., 2008
14	21	Diet +/- LPS challenge +/- 0.15% Gln	- Increased average daily gain - Limited pro-inflammatory response due to LPS challenge - Preserved intestinal integrity by increasing Villus height: crypt depth ratio	Jiang et al., 2009

LPS: Lipopolysaccharides

Table 3- Overview of growth performance of weaned piglets and of other species when replacing different protein sources with Solpro® (Manufactured by Tereos).

Species	Period, day	Treatment	Average daily gain	Feed intake	Feed efficiency	References
			Piglets			
Weaned Piglet 21 days of age	35	10% Fish Meal replaced with 9.5% HWP	=	=	=	Blasco et al., 2005
Weaned Piglet 21 days of age	45	5% HWP in phase 1 to replace skim milk powder and spray-dried porcine plasma; and 3% in phase 2 to replace SDPP and fishmeal	=	=	=	South Dakota trial, 2005; Tereos data
Weaned Piglet 21 days of age	28	8% Spray-dried porcine plasma replaced with 8% HWP	=	=	=	Lai et al., 2004
			Other Species			
Broiler	21	5% Soy Isolate replaced with 5% HWP	=	↓	↑	Van Leeuwen et al., 2004
Calf	140	15% Skim milk protein replaced with HWP	=	=	=	Ortigues-Marty et al., 2003
Juvenile Hybrid Sturgeon	56	0 to 5% Soy Protein Concentrate replaced with 0 to 5% HWP	↑	=	↑	Qiyou et al., 2011
Rainbow trout	56	0 to 50% high quality fishmeal replaced by HWP	=	=	=	Storebakken et al., 2015

HWP: Hydrolysed wheat proteins (Solpro®), SPC: Soy protein concentrate
↑/↓: significant increase/decrease of the parameter when replacing protein sources with hydrolysed wheat proteins ($P < 0.05$).
=: no significant increase/decrease of the parameter when replacing protein sources with hydrolysed wheat proteins ($P > 0.05$).

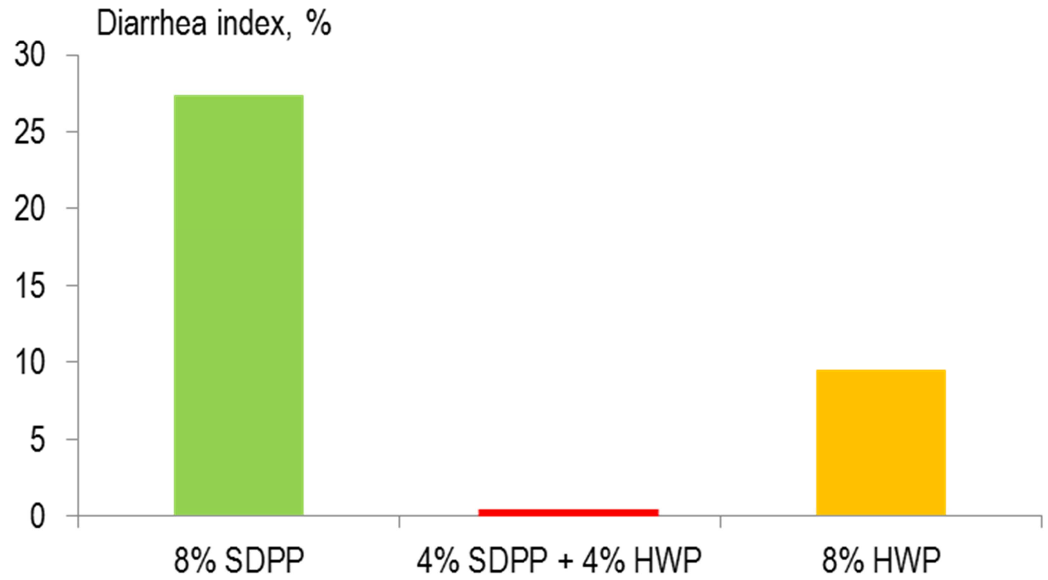

Figure 1- Diarrhea index of piglets fed SDPP, SDPP-HWP and HWP diets. Diarrhea index is calculated as DI (%) = (the number of pigs with diarrhea×the number of days pigs had diarrhea)/(108 experimental pigs×28 experimental days). Adapted according to Lai et al., 2004.

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