CNU Journal of Agricultural Science Vol. 42, No. 3, pp. 207-213, September 2015

DOI: http://dx.doi.org/10.7744/cnujas.2015.42.3.207

Value of spray-dried egg in pig nursery diets

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Received on 17 August 2015, revised on 27 August 2015, accepted on 4 September 2015

Abstract : High-quality protein ingredients have been used in nursery diets, in spite of expensive ingredients, to minimize nutritional deficiency and disease problems. Recent dramatic increases in prices of protein products for nursery diets have exacerbated the challenge. Spray-dried egg may be a part of the solutions. Therefore, this review describes the value of spray-dried egg in nursery diets as a high-quality protein source. Spray-dried egg is egg by-product and is produced by only eggs without shell that are below the USDA Grade B standards. Spray-dried egg is an excellent nutrient source: 1) highly digestible, 2) excellent balance of amino acids, 3) rich content of fat, and 4) high metabolizable energy. These can be attributed to growth of nursery pigs. Beyond the provision of bioavailable nutrients, spray-dried egg also may provide specific physiological benefits. Spray-dried egg contains 1) immunoglobulin antibodies (IgY: IgG in egg yolk) that may attach to intestinal pathogens and excrete them and 2) lysozymes antimicrobial protein that can damage bacteria cell wall. Thereby feeding spray-dried egg may reduce concentration of intestinal pathogen and thus improve potential gut health or enteric disease resistance in nursery pigs. This is important for physiologically immature weaned pigs. Based on these benefits, spray-dried egg is believed to have the same benefits as spray-dried plasma protein and milk products in diets for nursery pigs. Therefore, it is suggested that spray-dried egg has a great potential as a valuable protein source in nursery diets.

Key words **:** Health, Nursery pigs, Nutrients, Spray-dried egg

I. Introduction

Weaning is a stressful event for nursery pigs. First, piglets are moved from a known to an unknown environment, are mixed with other piglets, and create social and behavioral changes. Second, piglets are removed from the sow, which previously provided protection from diseases through antibodies in her milk. The immune system of the newly weaned pig is still relatively immature and, therefore, it is very susceptible to diseases. Third, the weaned piglet is switched from a liquid diet of sow milk to a solid feed. It needs to learn to consume the feed and has to develop the digestive capacity to break down the feed into nutrients that can be absorbed. Therefore, providing the proper feed is important for piglets after weaning to transit smoothly from sow milk to solid feed and to minimize the post-weaning performance. Thus most ingredients for nursery diets are highly digestible, energy-rich, balance of amino acid, as well as highly expensive.

Formulation of high-quality but low-cost pig nursery diets for use in the competitive pork industry continues to be a challenge. In fact, still keeping expensive in prices of soybean meal and plasma protein and recent dramatic increases in prices of fish meal and milk products have exacerbated the challenge.

Spray-dried egg (SDE) may be part of the solution, providing nutrients, immunoglobulins, and other physiologically active compounds. In this review, value of spray-dried egg is described as one of

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excellent protein ingredients in pig nursery diets. It is anticipated that more researches about SDE in nursery diets will be performed based on this review and SDE will be used as a protein source in nursery diets.

II. Definition of spray-dried egg

Association of American Feed Control Officials (AAFCO, 2008) mentions about SDE that 'Egg product is the product obtained from egg graders, egg breakers, and/or hatchery operations that is dehydrated, handled as liquid, or frozen. This product shall be free of shells or other non-egg materials except in such amounts which might occur unavoidably in good processing practices, and contain a maximum ash content of 6% on a dry matter basis.'. There are two types of SDE in marketing now and both of them are called spray-dried egg and are approved by AAFCO as the egg product. One is produced by only eggs without shell and the other one is produced by eggs without shell including hatchery wastes, not only eggs. This review is focused on SDE is produced by only eggs without shell and thus definition of SDE can be described as an egg by-product that is produced by only eggs without shell that are below the USDA Grade B standards which have thinner whites and wider and flatter yolks than higher grades eggs and have intact shells (Norberg et al., 2004).

III. Egg production and how to produce spray-dried egg

In the US, there are approximately 280 million laying hens and each hen produce approximately 260 eggs per year (United Egg Producers (A National Egg Producer Organization), 2008) and thus 72.8 billion eggs per year are produced. However, roughly 2.18 billion (3% of the total eggs produced) eggs are unsuitable for human consumption (Norberg et al., 2004). Eggs that do not meet grade B or equivalent standards are used to make liquid, frozen, dried egg products for cooking, or by-products for animal feeds (Cunningham and Acker, 2001; Norberg et al., 2004; Schmidt et al., 2007).

Norberg et al. (2004) described that 'SDE is prepared by removing the shell and mixing the yolk and albumen together. The mixture of yolk and albumen is pasteurized and then sprayed into an oven that is heated to approximately 70°C, producing a powder with approximately 4.25% moisture. The finished product must test negative for *Salmonella* before inclusion into a diet.'

IV. Provision of bioavailable nutrients

1. Excellent Balance of Amino Acids

Feed ingredients are normally evaluated on the basis of their contributions of bioavailable nutrients. SDE is an excellent nutrient source for nursery pigs because of excellent balance of amino acids. SDE generally contains a large proportion of egg whites (albumen) (Rose et al., 1974; Schmidt et al., 2003), which has an excellent amino acid profile. SDE contains a relatively high level of methionine, tryptophan, and valine compared to other general protein ingredients for nursery diets (Table 1).

2. High Digestibility of Amino Acids

SDE is an excellent nutrient source for nursery pigs because of high digestible ingredient. Norberg et al. (2004) showed apparent and true amino acid digestibility for ducks fed SDE, plasma protein (PP), and soybean meal (SBM) with nitrogen free ingredient such glucose or dextrose. Apparent and true amino acid digestibility of ducks fed SDE is almost similar in those of ducks fed PP or SBM. Schmidt et al. (2003) also showed

Table 1. Amino acid composition of spray-dried egg and other general protein ingredients for nursery diets (as-fed basis; as % of crude protein)

	Ingredients							
Item (%)	SDE[a)]	SDE[b)]	SDE[c)]	Average[d)]	SBM[e)]	Fishmeal[f)]	Dried whey[g)]	SDP[h)]
Crude protein	50.18	49.00	53.56	50.91	47.50	62.90	12.10	78.00
Arginine	6.00	6.14	6.24	6.13	7.33	5.82	2.15	5.83
Histidine	2.23	2.33	2.91	2.49	2.69	2.83	1.90	3.27
Isoleucine	5.66	5.27	5.17	5.37	4.55	4.09	5.12	3.47
Leucine	8.71	8.47	8.91	8.69	7.71	7.22	8.93	9.76
Lysine	7.27	6.88	7.95	7.37	6.36	7.65	7.44	8.77
Methionine	3.23	3.12	4.72	3.69	1.41	2.81	1.40	0.96
Phenylalanine	5.20	5.39	5.94	5.51	5.03	3.99	2.98	5.67
Threonine	4.30	4.33	5.02	4.55	3.89	4.20	5.95	6.05
Tryptophan	2.15	1.94	-	2.05	1.37	1.05	1.49	1.74
Valine	6.64	6.49	6.37	6.50	4.78	4.82	4.96	6.33

[a)]Spray-dried egg, DeRouchey et al., 2003.
[b)]Spray-dried egg, Figueiredo et al., 2003.
[c)]Spray-dried egg, Norberg et al., 2004.
[d)]Average value is from DeRouchey et al., 2003, Figueiredo et al., 2003, and Norberg et al., 2004.
[e)]Soybean meal without hulls, NRC, 1998.
[f)]Menhaden fishmeal, NRC, 1998.
[g)]NRC, 1998.
[h)]Spray-dried plasma, NRC, 1998.

Table 2. Digestibility of spray-dried egg and plasma protein or soybean meal in ducks and pigs.

	Ducks[a)]						Pigs[b)]	
	Apparent amino acid digestibility			True amino acid digestibility			Ileal digestibility	
Item (%)	SDE[c)]	PP[d)]	SBM[e)]	SDE	PP	SBM	SDE	SDPP[f)]
Indispensable								
Arginine	95.21	94.05	95.83	97.10	95.94	97.27	88.10	84.40
Histidine	87.81	92.61	91.58	93.40	98.20	97.20	93.50	78.90
Isoleucine	93.85	91.57	92.06	96.38	94.10	94.59	89.80	78.60
Leucine	93.75	93.00	91.83	96.30	95.55	94.38	78.50	81.40
Lysine	92.29	92.78	92.78	94.47	94.96	94.95	84.10	82.40
Methionine	95.53	88.30	91.26	97.00	89.78	92.73	96.30	85.30
Phenylalanine	93.95	92.73	93.05	96.39	95.16	95.48	87.50	81.70
Threonine	91.57	92.54	88.85	95.86	96.83	93.13	85.60	70.80
Tryptophan	96.57	94.27	95.68	97.89	95.58	96.99	-	-
Valine	81.52	92.82	90.71	89.21	100.51	97.89	86.70	77.80
Dispensable								
Alanine	89.94	89.84	85.70	94.69	94.60	90.45	85.20	77.60
Aspartic acid	92.12	92.04	92.71	95.14	95.07	95.74	67.10	75.50
Cysteine	88.41	92.35	85.14	93.65	97.32	93.11	92.00	70.50
Glutamic acid	92.30	92.47	94.42	95.63	95.81	97.76	56.50	82.20
Proline	83.87	91.77	89.83	93.12	101.02	99.09	82.50	75.40
Serine	88.34	92.15	90.59	90.98	94.80	93.23	82.00	73.50
Tyrosine	94.70	94.24	93.00	97.39	96.93	95.67	93.20	79.90
Glysine	-	-	-	-	-	-	83.20	61.50

[a)]Norberg et al., 2004.
[b)]Schmidt et al., 2003.
[c)]Spray-dried egg.
[d)]Plasma protein.
[e)]Soybean meal.
[f)]Spray-dried porcine plasma.

Table 3. The level of fat and metabolizable energy of spray-dried egg and other general protein ingredients for nursery diets (dry matter basis).

Item	Ingredients							
	SDE	SDE[a)]	SDE[b)]	Average[c)]	SBM[d)]	Fishmeal[e)]	Dried whey[f)]	SDP[g)]
Dry matter, %	-	94.05	92.70	93.38	90.00	92.00	96.00	92.00
Crude fat, %	31.108	32.96	23.89	29.31	3.33	10.22	0.94	2.17
ME, Mcal/kg	5.099	-	-	5.09	3.76	3.65	3.32	4.24

[a)]Spray-dried egg, Norberg et al., 2004.
[b)]Spray-dried egg, Figueiredo et al., 2003.
[c)]Average value is from Norberg et al., 2001, Richert and Harmon, 2007, Norberg et al., 2004, and Figueiredo et al., 2003.
[d)]Soybean meal without hulls, NRC, 1998.
[e)]Menhaden fishmeal, NRC, 1998.
[f)]NRC, 1998.
[g)]Spray-dried plasma, NRC, 1998.

apparent ileal amino acid digestibility for pigs fed SDE and spray-dried porcine plasma (SDPP) with common basal diet. Apparent ileal amino acid digestibility of pigs fed SDE with common basal diet is also almost similar in that of pigs fed SDPP with common basal diet, although this experiment didn't measure apparent ileal amino acid digestibility of only SDE or SDPP.

3. High Fat and Metabolizable Energy

SDE is an excellent nutrient source for nursery pigs because of rich content of fat and high metabolizable energy. SDE contains higher fat content (about 30%) than other general protein ingredients for nursery diets (Table 3). Pigs fed SDE have higher metabolizable energy (about 5 Mcal/kg) than pigs fed other general protein ingredients for nursery diets (Table 3).

4. Effect of Spray-Dried Egg on Growth performance

Based on above beneficial bioavailable nutrients of SDE, several experiments were conducted to evaluate effect of SDE on growth performance of pigs. However, the effect of SDE on growth performance of nursery pigs has not been conclusive. For example, some researches replaced spray-dried plasma (SDP) with SDE and showed that there is no or lower growth effect of pigs fed SDE (Figueiredo et al., 2003; Norberg et al., 2001; Schmidt et al., 2003) or some researches replaced soybean meal with SDE and showed that there is higher or no growth effect of pigs fed SDE (DeRouchey et al., 2003; Shao et al., 2003).

Based on above bioavailable nutrients benefits of egg, dietary supplementation of SDE may be one of good protein sources in nursery diets as growth performance is not reduced.

V. Provision of specific physiological benefits

Certain feed ingredients provide specific physiological benefits beyond the provision of bioavailable nutrients, and these are especially important in diets for physiologically immature newly weaned pigs. For example, SDP, milk products, and now SDE are routinely forced into early nursery diets. Plasma, milk, and eggs all contain immunoglobulins and other physiologically active components, and they share the role of transporting those components from one part of the body to others (plasma) or from mother to offspring (milk and eggs). Therefore, egg products have been purported to share some of the benefits of SDP and milk products in diets for young pigs.

5. Immunoglobulins in Spray-Dried Egg

Egg contains immunoglobulin. Rose et al. (1974) reported that the concentration of immunoglobulin G (IgG) in hen serum is about 6 mg/ml, that of immunoglobulin Y (IgY; Generally, most IgG in hen serum is transferred to egg yolk, which is called IgY (IgG in egg yolk)) in egg yolk is about 25 mg/ml, that of IgY in egg whites is less than 0.003 mg/ml, and thus that of IgY in SDE is about 30,000 ppm. However, Akita and Nakai (1992) reported the concentration of IgY in egg yolk is about 10 mg/ml and thus that of IgY in SDE is about 12,000 ppm (Harmon et al., 2002). Based on both reports, the concentration of IgY in egg yolk is much higher that that of IgG in hen serum and SDE contains high level of IgY. Therefore, SDE may contribute benefits beyond provision of nutrients.

6. Effect of Immunoglobulins in Spray-Dried Egg

Immunoglobulins and other physiologically active agents are transmitted from the hen to her chicks through the egg, so it may be reasonable to postulate that adding eggs to the diet may impact pig performance. Chicken IgY antibodies can be compared to IgG antibodies obtained by conventional immunization methods (Tini et al., 2002). Chicken egg-yolk immunoglobulins do not interfere with mammalian IgG and they do not activate mammalian complement. These characteristics confer advantages to the application of IgY as antibiotic-alternative therapy (Tini et al., 2002). Thus, dietary supplementation of egg products may be expected to provide protection to neonate animals. However, there is little evidence for a beneficial effect of SDE.

Although there have been no published researches about benefit of IgY in SDE, on the other side of egg products, there are several researches about immune egg products. Hens can be immunized against pig pathogens, so they produce antibodies against those pathogens and deposit them in the yolk of the eggs they produce. Feeding the yolk to pigs provides passive immunity to the target disease. Based on this concept, many researches were focused on IgY to prevent *E. coli* pathogens because diarrhea in neonatal and post-weaning pigs is a significant and persistent problem in pig production and among the major causes of diarrhea in piglets are enterotoxigenic *E. coli* (ETEC) strains expressing K88, K99 and 987P fimbrial antigens (Jin et al., 1998). Several studies showed immuned egg yolk reduces adherence and colonization of ETEC strains, mortality, clinical signs, or diarrhea score in neonatal pigs (Imberechts et al., 1997; Marquardt et al., 1999; Owusu-Asiedu et al., 2002; Yokoyama et al., 1997; Zuniga et al., 1997). It indicates that immune egg products may be attributed to antibacterial antibodies and subsequent reduction of gastrointestinal bacterial infections.

7. Lysozyme in Spray-Dried Egg

Egg also contains lysozyme as one of antimicrobial proteins in egg whites. Lysozyme is a relatively low-molecular-weight protein composed of 129 amino acid residues enzyme hydrolase which catalyze hydrolysis of 1,4-β-linkages between N-acetylmuramic acid and N-acetyl-D-glucosamine residues in peptidoglycan (Cunningham et al., 1991). This catalytic activity can damage bacterial cell walls, but it is only effective against gram positive bacteria. However, several researches showed enhancement of this catalytic activity of lysozyme by heating or irradiation can reduce the survival rate of gram negative bacteria as well as gram positive bacteria (Ibrahim et al., 1996; Schmidt et al., 2007). Therefore, SDE may contribute benefits beyond provision of nutrients.

8. Effect of Lysozyme in Spray-Dried Egg

Based on these benefits from lysozyme, dietary supplementation of egg products may also be expected to provide protection to neonate animals. However, there is also little evidence for a beneficial effect of SDE. Schmidt et al. (2003) showed *Enterobacteriaceae* counts in pigs fed the spray-dried technical albumen (SDTA) and SDTA stored in a hot room (70°C) for 3 d (SDTA-ht) SDPP are not different from pigs fed SDPP control diet, but pigs fed the spray-dried whole egg are the highest *Enterobacteriaceae* counts. It indicates that denatured SDE may be attributed to reduction of gastrointestinal bacterial infections.

Based on above specific physiological benefits of egg, dietary supplementation of SDE may be expected to provide protection to nursery pigs. However, there is little evidence for a beneficial effect of SDE. It is clear that SDE are less efficacious than SDP in stimulating pig growth. However, there remains the possibility that SDE can provide benefits, even if those benefits are smaller than the impressive ones provided by plasma (Pettigrew, 2006).

VI. Conclusion

Spray-dried egg has a big possibility to one of common protein sources for nursery pigs. It provides bioavailable nutrients and may provide physiological benefits beyond the provision of bioavailable nutrients. Additional researches are needed to confirm effect of spray-dried egg on growth performance of nursery pigs and to verify roles and mechanisms of immunoglobulins or lysozymes in spray-dried egg when nursery pigs fed spray-dried egg.

Acknowledgements

This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ01088202)" Rural Development Administration, Republic of Korea.

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