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Emulsifiers in the poultry industry

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Emulsifiers are used in poultry nutrition for improving poultry performance, digestibility of the nutrients, especially fats, and include soy-lecithin, milk derived casein, lysophatidylcholine or lysolecithin (lecithin), bile salt, glycerol polyethylene glycol ricinoleate (E 484), and sodium stearoyl-2-lactylate (SSL) etc. The efficacy of emulsifying agents can be used with different vegetable oils and various levels of metabolisable energy (ME). The literature shows that the selection of various natural and synthetic sources of emulsifiers should be on the basis of their hydrophilic-lipophilic balance (HLB). There are new directions regarding exogenous and natural emulsifying agents, their blends in poultry diet and importance of *in vitro* studies. The following review includes comparisons of emulsifying agents and their impact on performance in poultry.

Keywords: poultry production; emulsifier; digestion; broiler; diet

Introduction

In poultry diets, animal fats and vegetable oils are mostly included in diets because of their high energy concentration to support growth performance (Blanch *et al.*, 1996). Enzymatic hydrolysis of lipids (oils and fats) produces fatty acids (FA) which are water insoluble. FA passes through the liquid phase of the small intestine and, after aggregating to form micelles, are absorbed as hydrophobic components. This process is naturally mediated by endogenous emulsifiers, such as bile salts. The assimilation of dietary fats in young birds is poor because they have a limited capacity to produce and secrete bile salts and lipase until their gastrointestinal tract matures at 10-14 days of age (Noy and Sklan, 1998). This immaturity leads to an inability to form mixed micelles in the intestinal lumen of the birds which reduces fat digestion and absorption of nutrients (Leeson and

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Atteh, 1995). Studies have indicated that age has an effect on ME values and growth performance. This has led to considerable interest in the potential of exogenous emulsifier preparations in order to improve the utilisation of fats in young birds (Azman and Ciftci, 2004; Ashraf, 2007; Roy *et al.*, 2010).

Energy is a major cost component factor in diets of high performance animals, such as broilers. Emulsifiers can be used to improve fat digestibility and energy efficiency. As a result, lower energy diets can be formulated for birds whilst maintaining the same performance, leading to lower feed cost and more economical and sustainable production. Emulsifiers facilitate the formation of emulsion droplets, which lowers the surface tension (Ashraf, 2007), stimulates the formation of micelles, causes high levels of monoglycerides in the intestine and facilitates the nutrient transport through the membrane (Melegy *et al.*, 2010). The use of emulsifiers in poultry diets have increased feed efficiency, lipids absorption, growth performance and modified the lipids present in the blood (Udomprasert and Rukkwamsuk, 2006). However, other researchers reported that the supplementation of emulsifiers in diet elevated digestibility of nutrients, but has less effect on carcass traits and growth performance (Xing *et al.*, 2004; Jones *et al.*, 1992).

Low cost emulsifying agents or detergents which transform a hydrophobic surface into a hydrophilic environment have been used to increase fat digestibility in young chicken (Al-Marzooqi and Leeson, 1999). Soy lecithin is a known emulsifier which promotes incorporation of fatty acids into micelles and improves fat digestibility in chicken (Polin, 1980). Polyoxyethylene glycol mono- and dioleates are synthetic emulsifiers and have been used on other animals, such as pigs, although *in vivo* emulsification tests indicated that synthetic emulsifiers were not as e□ective as bile salts (Frobish *et al.,* 1969). However, the demand of using exogenous emulsifiers in broiler diets must be looked into the use of nutrient dense diets containing supplied fat that is almost usual to take advantage of the full growth potential in fast growing broiler strains.

The main purpose of this review is to highlight the importance and uses of emulsifiers in the broiler industry, for assisting greater awareness for researchers, scientists, veterinary professionals, poultry producers/owners as well as examining applications in the poultry industry.

Digestibility problems in young chicks

Commercial poultry feeds are commonly supplemented with fats and oils to provide higher energy density. However, it must be considered that fat absorption increases with bird age, as young broilers have a physiological limitation to absorb that nutrient (Jeason and Kellog, 1992; Nir *et al.*, 1993; Lima *et al.*, 2003). The inability of young birds to absorb fat efficiently has been attributed to its poor emulsification ability and poor lipase activity; however, these biological processes improve with the age and adapt to cope with higher unsaturated fatty acids (Meng *et al.*, 2004).

However, the addition of high levels of saturated fat to broiler rations may result in excessive visceral and carcass fat, inadequate vitamin A and E and poorer meat quality (Chae *et al.*, 2006; Zulkifli *et al.*, 2007). Differences in the digestibility of various fats affects animal performance, especially in non-ruminants, and the composition of dietary lipids is an important factor for the digestibility of the fat and therefore the extent to which it can be used as a source of metabolisable energy in chickens (Wiseman, 1984). It has been established that the addition of fat containing a high proportion of unsaturated fatty acids and/or phospholipids to one with a preponderance of saturation will enhance the absorption and subsequent dietary energy value of the latter (Renner and Hill, 1961;

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Sibbald, 1978; Sibbald and Kramer, 1980; Leeson and Atteh, 1995; Smits *et al.*, 2000). Phospholipids are known to have surface active properties. They are important in the emulsification of lipids and may influence the absorption of fatty acids in the small intestine (Jenkins *et al.*, 1989).

What are emulsifying agents?

An emulsifying agent is a substance that stabilises an emulsion and prevents the coalescence of the globules of the dispersed phase. An emulsion is a mixture of two products such as oil and water that do not mix together *i.e.* that are immiscible. Adding an emulsifying agent (emulsifiers or emulgents) to the mixture causes the oil to be broken down into smaller pieces that can then be dispersed throughout the water. The emulsifier's action is made possible by reducing the tension between the two phases and creating a constant interfacial film.

In the formulation of a stable emulsion, selecting suitable agents is important as different types have variable effects. Soluble substances in both fat and water allow fat to be equally dispersed in water as an emulsion. These substances have both a hydrophilic and lipophilic component in their chemical structure. The emulsifiers are absorbed into the oil-water interface to provide a defensive barrier around the dispersed droplets. They stabilise the emulsion by reducing the interfacial tension of the system. Some emulsifying agents increase constancy by imparting a charge on the droplet surface, thus lowering the physical contact between the droplets and reducing the potential for coalescence. Some commonly used emulsifying agents include sodium dioctyl sulphosuccinate, sodium laurylsulphate, tragacanth and other polymers known as the Spans and Tweens.

Fats are insoluble in water and cannot be solubilised in the gastrointestinal tract, and have to be emulsified before lipolytic enzymes can digest them. Emulsification depends on the characteristics of the fat such as chain length, position of fatty acids on the triglycerides and fat saturation (Gu and Li, 2003). Emulsifiers help to improve the utilisation of lipids, particularly animal fats, and play a role in performing the insufficiencies of naturally low bile production and recirculation in young birds.

Commercial agents which are usually used in the feed industry can be categorised as two groups (natural and synthetic emulsifiers). Natural ones are those produced in the animal body such bile and phospholids, and those from food materials such as soy lecithin (Soares and Lopez-Bote, 2002) Synthetic emulsifiers that are modified emulsifiers such as lysolecithin or lysophosphatidylcholine (Zhang *et al.,* 2011).

Bile salts are natural emulsifiers, and monoglycerides formed after hydrolysis of fat act as emulsifiers. However, the capacity of these natural emulsifiers can be a constraint for fat digestion. Young birds have inadequate portions of bile salt production so fat digestibility is poor in the early stage of life, and the characteristics of dietary fat can limit digestibility. High amounts of free fatty acids cause poor monoglyceride formation and consequently have a poor emulsifying capacity. Long chain unsaturated fatty acids and monoglycerides form micelles rapidly, whereas saturated fatty acids have low ability to form micelles because of their weak polarity. A list of emulsifiers that are usable in poultry industry is presented in *Table 1*.

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Table 1 Available emulsifiers used in poultry industry.

Natural emulsifiers	Major effects	References
Soy-lecithin	Improved performance, HDL, triglycerides, insulin (INS), Thyroid stimulating hormone (TSH) and hepatic expression of lipogenic genes and decreased TC and LDL level in blood serum	Siyal *et al.,* 2017 Huang *et al.,* 2007
Milk- derived casein	Increased weight gain, FCR, pancreatic lipase, improved ether extract digestibility with no effect on carcass traits, serum cholesterol, HDL and triglycerides	Guerreiro *et al.,* 2011
Lysophosphatidylcholine or lysolecithin (lecithin)	Improved weight gain, FCR, co-efficient of total tract apparent digestibility(CTTAD) of C16:0,C18:2,and C18:3n3, C18:1n7 and C18:1n9 fatty acids, improved carcass quality and dressing percentage	Melegy *et al.,* 2010 Zhang *et al.,* 2011 Azman and Ciftci, 2004 Ashraf, 1995
Bile salt	Improved relative weight of organs Significantly improved BWG Decreased plasma cholesterol Increase metabolisable energy Enhance the broilers performance and the digestion enzyme activeness of intestinal tract contents	Abd-El-Rauof, 1995 Alzawqari *et al.,* 2010 Gomez and Polin, 1976 Kussaibati *et al.*, 1982 Zhong and Xiang, 2008
Synthetics emulsifiers		
Glycerol polyethylene glycol ricinoleate, E 484	Improved performance, intake and utilisation efficiency of fat, CP, ME and	Roy *et al.,* 2010
Liprex poultry	Increased the body weight and liver weight	Yordan *et al.,* 2013
Sodium stearoyl-2-lactylate (SSL)	Improved body weight and relative organs weight	Flores *et al.,* 2007 Chronakis *et al.*, 2004

Hydrophilic-lipophilic balance

The combination of hydrophilic and lipophilic characteristics in one molecule gives it the distinctive property that the emulsifier can dissolve in fat as well as in water, and can aid in mixing the two fractions. The key indicator for selecting an emulsifier is hydrophilic-lipophilic balance (HLB), ranging from 0 to 20 which reveals the degree of fat or water solubility. Lower HLB indicates a more lipophilic or fat-soluble emulsifier. On the other hand, higher HLB indicates a more water soluble or hydrophilic emulsifier.

Ideally, the emulsifier should be soluble in the continuous phase as the Bancroft rule states (1912). For the soluble condition known as the 'fat-rich environment' mixed in a small amount of water, an emulsifier with a lower HLB is advised, and *vice versa*. Because of birds consume water 1.5-2 times more than feed; the diet should contain a small amount of fat and the water amount should exceed fat in digestive tract. In this situation, a high HLB is more appropriate.

Use of emulsifiers in animal diet

Use of exogenous emulsifier can be made necessary due to supplementing high levels of vegetable or animal fat for improving growth potential. Fat utilisation in young birds is

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poorly developed and a marked improvement of the apparent metabolisable energy (AME) value of fats has been reported in birds that are 1.5 to 3.5 weeks of age (Wisman and Salvador, 1989). Natural emulsifiers like soy lecithin cause absorption of fatty acids into micelles and improve fat digestion in chicks (Polin, 1980). Lecithin structure contains choline which is effective in preventing perosis in birds (Schaible, 1970).

Synthetic emulsifiers like polyoxyethylene glycol mono and dioleates gave good results in utilisation of fat (Frobish *et al.*, 1969). An emulsifier in the diet is helpful to increases the total enzymatic surface needed for digestion of fats (Jones *et al.*, 1992; Roy *et al.*, 2010).

There are several emulsifiers that have been used in animal/poultry diets and gave good results *i.e.* soy-lecithin, a by-product from the processing of soybean oil, which not only makes available more energy to broilers, but also serves as an emulsifier to enhance digestion of fat. Jin *et al.* (1998) reported that adding lecithin to tallow improved the digestibility of gross energy, dry matter, ether extract and crude protein in piglets. Lecithin has been considered for using in animal diets, such as sheep (Jenkins and Fotouhi, 1990), lambs (Lough *et al.,* 1991), horses (Holland *et al.,* 1998), swine (Overland *et al.,* 1994; Soares and Lopez-Bote, 2002), fish and crustacean larviculture (Coutteau *et al.,* 1997), but has limited data in poultry. Among emulsifying agents, casein has become an important feed additive. The main source of casein is skimmed milk powder and soluble caseinates, which are heterogeneous protein aggregates, and are the most important components included in the emulsification of beta-casein, and proline residues (Araujo, 1999). Supplementation of bile salts in poultry diets increased fat digestion but this may not be economically viable (Al-Marzooqi and Leeson, 1999). Synthetic emulsifiers like polyoxyethylene glycol mono and dioleates have been used in pig diets but not in poultry as yet, although the *in vivo* emulsification of fat by the synthetic emulsifiers was not as efficient as that obtained with bile salts (Frobish *et al.,* 1969).

Major effects of emulsifier substances

Supplementation with emulsifiers in poultry feed has been determined to increase utilisation e□ciency of dietary fat and improve live body weight and FCR in broiler chickens (Siyal *et al.,* 2017; Dierick and Decuypere, 2004; Jones *et al.,* 1992). Supplying an emulsifier in broiler diet is more important during the early age (Sell *et al.,* 1986) because lipase activity in chickens reaches at its peak usually during 40-56 days of age (Krogdahl and Sell, 1989). In addition, synthesis of bile salts remains at a low level in early birds (Serafin and Nesheim, 1970; Smallwood *et al.,* 1970; 1972), and bile salts added to diets caused better fat absorption (Polin, 1980) and improved performance in young chickens (Frobish *et al.,* 1969; Jones *et al.,* 1992; Overland *et al.,* 1994; Jin *et al.,* 1998; Dierick and Decuypere, 2004; Dersjant and Peisker, 2005). Birds supplemented with 0.5% soy-lecithin and 1.5% soy-oil increased performance, while chickens fed with 2% lecithin revealed poor performance (Huang *et al.,* 2007).

Exogenous emulsifiers used in broiler diet revealed that these synthetic products caused no increase in morbidity and mortality (Guerreiro Neto *et al.,* 2011) and do not affect feed intake (Ashraf, 2007; Roy *et al.,* 2010; Guerreiro Neto *et al.,* 2011; Yao *et al.,* 2012). Lysophosphatidyl choline acted as an emulsifier on broiler chicken performance, but did depend on the type of oil (Zhang *et al.,* 2011). Emulsifiers are more effective in birds supplemented with soybean oil (rich in polyunsaturated fatty acids), in comparison with palm oil (saturated fat) (Guerreiro Neto *et al.,* 2011). Various researchers reported

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beneficial results on digestibility, BW, FCR, weight gain and abdominal fat in broiler chicks, respectively caused by with exogenous emulsifiers (Udomprasert and Rukkwamsuk, 2006; Roy *et al.,* 2010). However other reports on broiler chicken trials showed that exogenous emulsifier has no significant effect on productive indicators and lipid profile, however it improved ME and palm oil (Yordan *et al.,* 2013).

Effects on serum parameters

Concentrations of lipoproteins and plasma lipids are representative of metabolic regulation and the basal adjustment of fatty acid transfer between the adipose tissue and the liver (Amal *et al.,* 2002). Studies have determined that lecithin, a phosphatidylcholine containing phospholipid, has hypocholesterolemic properties (Thomas *et al.,* 1998). Huang *et al.* (2007) reported birds fed a diet supplemented with soy-lecithin resulted in a lower serum concentration of total cholesterol (TC) and LDL- C (Jones *et al.,* 1992; Thomas *et al.,* 1998), whereas serum concentrations of HDL-C and triglyceride (TG) were elevated. In a further study, soybean emulsifier products significantly reduced total and LDL-cholesterol and TG levels (Ristic *et al.,* 2003) whereas HDL cholesterol was significantly elevated and phospholipid fatty acid content was optimised after 24 weeks feeding.

Plasma metabolic hormones like insulin, glucagon and T3 are valuable factors which indicated the level of hepatic lipogenesis of birds (Hillgartner *et al.,* 1995). It has been observed that circulating levels of thyroid stimulating hormone (TSH) increased when 2% crude soybean lecithin was supplemented in broiler diets, but no significant differences were observed on serum free fatty acids (FFA) and T4, although T3 concentration declined compared with other groups (Huang *et al.,* 2007).

Conclusions

Exogenous nutritional emulsifiers can be helpful in digestion of fatty acids. Clearly, the positive effect of adding such emulsifiers is indicated in poorly digestible fats than highly digestible fats. This positive effect is more noteworthy when high levels of fats are included in diets. However, with higher level of digestible fats, positive effects have still been observed. The efficacy of emulsifiers depends upon the type of oil used in the broiler diets. The function of nutritional emulsifier is to enhance the digestibility of long chain fatty acids, especially saturated fatty acids (SFA) C16 and C18. Hence emulsifiers could have an important role in economic aspects in poultry industry since they increase efficiency in digestion of both animal and vegetable fats. Metabolisable energy of the diet is a key factor and emulsifiers have showed positive results on performance, fat digestibility, immune response and blood metabolic hormones while used in a high ME diet.

The selection of an emulsifier and type of oil is an important step for obtaining good performance results. The HLB should be used as part of the selection process, as it indicates fat and water solubility on a range from zero to 20. Lower HLB products are more fat soluble, while higher HLBs are more water soluble. When feeding poultry, a higher number would be desirable because the content of the gut is more watery. However, no one has focused on the economy of oil and emulsifiers used in poultry rations. Most of the research has been conducted on soya bean oil, although palm oil is more economical and shows better performance. From the available literature, it is clear that attention must be paid to the type of oil used in feed and applying cheaper

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emulsifiers in order to formulate more economical diets as well as to explore the efficacy of emulsifiers in the broiler diets.

In addition, that no one has focused on the humidity and temperature; because both have a great impact on performance of broilers and the utilisation of concentrated energy forms such as fat and more attention is needed on the efficacy of emulsifiers when ambient temperature and humidity is high. Most studies have been conducted in broilers and other poultry species should be investigated to give expected outcomes from fat and emulsifier use. No one has paid interest to the blends of emulsifying agents, because there are both natural and synthetic sources of emulsifier, and this would be useful to understand to allow optimal emulsification recommendations. Not only this, but most of the studies are conducted on natural emulsifiers therefore some importance must be given to synthetic or exogenous emulsifying agents. Studies have focused on *in vivo* studies therefore; in future *in vitro* studies are need to be conducted on natural as well as synthetic emulsifiers.

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