Direct RESEARCH JOURNALS
Vol.4 (9), pp. 271-279, September 2016
ISSN 2354-4147
Article Number: DRJA32438754

Direct Research Journal of Agriculture and Food Science
http://directresearchpublisher.org/aboutjournal/drjafs

Research Paper

Using Unmarketable Egg Powder as Protein Supplement in Pre Ruminant Lamb Milk Replacer

A. N'DIAYE WEREME[1]*, J. F. GRONGNET[2] and D. GELBCKE[3]

[1]CREAF/INERA, Animal Production Department,01 BP 476 Ouagadougou 01 Burkina Faso.
[2]INRA, Laboratory of Young Ruminant, 65 rue de Saint Brieuc, 35042 Rennes Cedex France.
[3]Rue Joaquim Mabuco 1854 Capoeiras 88090-060 Florianópolis SC, Brazil.
*Corresponding author E-mail: weremea@gmail.com.

Received 17 July 2016; Accepted 10 August, 2016

The present study was carried out to assess whether the powder from eggs unfit for human consumption can be recovered as a protein supplement in milk replacer of pre ruminant lamb. A total of 96 lambs were divided into 2 groups and received 2 diets based on milk: a control and an experimental milk containing 20 % of egg powder, from 24 h after birth to 4 weeks of life. Both diets are repeated 5 times, 10 batches using each 9 or 10 lambs per repetition. The hematocrit of lambs is measured at the second and fourth postnatal week. It is stand out from this study, a considerable gap between the 2 diets for lambs for all Zoo technique measured parameters: body weight, weight gain, consumption of milk powder, feed efficiency and hematocrit. This difference is at the expense of the experimental group for which it can be concluded that the unfit egg powder is not suitable for pre ruminant lambs, given various digestive disorders observed during the experiment.

Key words: Unfit egg powder, Lamb, Milk replacer, Performance.

INTRODUCTION

Pre-Lambing nutrition normally refers to the final 3-4 weeks of pregnancy. However it is important to understand that the last trimester of pregnancy results in a huge nutritional demand increase on the ewe. Typically 70% of fœtal growth occurs in last six weeks of pregnancy, rumen capacity becomes limiting and intake falls. It is essential to compensate for this reduced intake and align concentrate requirement with forage intake and quality. Body condition scoring coupled with scanning results should be used to batch ewes accordingly. Typically these groups will be triplets, twins and singles; with option of allowing an under conditioned ewe into the next group in the chain.

The production of milk replacers, which began in France in 1958, grew until 1983, and then decreased with the implementation of milk quotas in 1984 (Toullec, 1988).

It was followed by a sharp decline in stocks of skimmed milk powder and quantities produced and an increase in its price (Caugant, 1993). Protein nutrition of the ewe pre-lambing is critical. Normally we consider two types of protein in an ewe diet; Rumen degradable (RDP) and Digestible Undegradable sources (DUP). RDP can normally provide most of their requirement but in last 3 weeks pre-lambing DUP is essential to stimulate colostrum and milk production. Milk presents a source of basal nutrients for pre- ruminants.

But, it is more expensive than the other source of nutrients (Quigley, 2002). For this purpose, alternative feeds to be cheap and high nutrients are investigated in animals feeding. Recently, feeds of animal source were used to be alternative feeds in milk replacer (Quigley et al., 2000; Hara-Kudo et al., 2001).

It was therefore essential to diversify the sources of protein in the composition of breastfeeding to reduce their high prices due to the rise in cost of skim milk used also in the human diet. The best food was the skim milk powder with the addition of some fat substitutes. Appropriate technological treatments can reduce the adverse effects of these compounds.

As with plant proteins, tests, few indeed, were conducted, using animal proteins such as whey and fish protein in the diet of pre-ruminant. Egg is among those have been used as feeds, because, considerable number of eggs get cracked either during transport, storage or during marketing (Tood, 1996; Bell et al., 2001; Hara-Kudo et al., 2001) and most of these are not at consumable quality for human (Tood, 1996) and these eggs are cheaper according to whole milk. Besides, sometimes it is free. The incorporation of egg powder has also been initiated since the European regulation prohibits the use of "clear" hatchery eggs for human consumption (Sauveur, 1988). Egg is an important alternative feed ingredient that contains high quality crude protein and crude fat (Quigley, 2002). Its amino acid profile and biological value of protein are excellent (Yamamoto et al., 1997). They are high in nutrients (highly nutritious) yet their high quality protein is used as a standard for the assessment of the protein quality of other feedstuffs (Tekinsen and Çelik, 1995). Fat contains significant lecithin, which can provide emulsifying properties to milk replacers (Quigley, 2002).

This raw material is interesting by its protein quality (about 48 % per kg dry material); energy intake and essential fatty acids inside. It has a good balance of essential amino acids (without limiting factor), with a wealth of methionine and cystine which milk is deficient (Thapon, 1981; Sauveur, 1988).

Moreover, numerous studies have shown the possibilities of modulation of the nutritional profile of the egg, which would also increase the share of eggs in the observed nutrient intake, for several nutrients. Combined with its low environmental impact, the nutritional quality of the egg could make this food one of the keys to a more sustainable food system (Nau et al., 2016). For adults, the World Health Organization associates potato to form the reference protein (Thapon, 1981). The egg is rich in protein; content is mainly composed of ovalbumin (54 % of egg white), ovotransferrin (12 %), ovomucoid (11 %), and lysozyme (3.5 %) (Abeyrathne et al., 2013). Other minor proteins are ovomacroglobulin (0.5 %, ovoflavoprotein (0.8 %) ovoglycoprotein (1 %); ovoinhibitor (1.5 %) (Kovacs-Nolan et al., 2005).

Unmarketable egg incorporation into livestock food might give better value to this alternative source of protein.

Moreover, the raw egg white is poorly digested and contains several anti-nutritional factors, mainly ovomucoid (glycoprotein) and egg inhibitor capable of inhibiting pancreatic proteases as trypsin and chymotrypsin (Goodale et al., 1988). The other components of egg, minor but important is avidin, a labile heat-resistant glycoprotein, with the property complex with biotin (vitamin H or $B_{8)}$, thereby, blocking its availability to the metabolic needs of the body absorption. The egg is against poor living in vitamin C and provides some calcium (Thapon, 1981). Its use in animal feed not dating today, the egg still holds its place in the rat race to innovation technologies, always looking for a better gain in the different branches of production.

In some researches, it was found that egg in milk replacer was affected negatively to feedlot performance and feed efficiency (Scott et al., 1999; Quigley, 2002), whereas in some authors reported that the protein in milk replacer of 15 % (Hill et al., 2000) and 30 % (Kellogg et al., 2001) will provide from egg.

In the past, few attempts have been made to the administration of the egg in the young pre-ruminant. Nau (1987) showed that some livestock trials were tempted with egg powder and date from the years 1956 to 1962. Investigations of Hoffmann (1971) have highlighted the deficiency symptoms in pigs, rats and chickens fed with egg.

It has been thought that, as a high quality nutrient, unmarketable cracked eggs could be used in animal nutrition and a few studies have been carried out on that respect. In these studies, eggs were used as a supplement to milk replacers following drying (Hill et al., 2000; Quigley, 2002; Scott et al., 1999). French industrial company to revive this untapped way to find an outlet for the downgraded hatchery eggs in order to incorporate them into animal feed.

This study aims to evaluate the nutritional performance of the use of the unfit egg powder incorporation of a threshold of 20%. The growth performance of lambs fed with this product were measured compared to those of lambs fed with conventional complete milk as control. The lamb (Romanov) was preferentially selected for essential reasons for easy handling by its small size, timing and race to have a large number of individuals in a short time, and especially for the low cost compared to the calf. It is understood that the results could be transposed in the calf, however, in making a preliminary study on this species.

MATERIALS AND METHODS

The experiment was conducted at INRA, Le Rheu Research Center in France. The local prepared to receive lambs was attached to a part of the barn that housed

pregnant ewes. All sampling equipment, weighing and food preparation was prepared in 2 specially equipped rooms. Another adjoining room served as rest one for the various groups responsible for monitoring calving and animal care.

Pets

Seventy-five Romanov and Rouge de l'Ouest ewes' multiparous and primiparous confused were covered (Romanov and Ile-de-France rams) five months earlier, grouped by natural crossing. They were standing in a closed stall barn where food (hay, concentrates and minerals) was distributed to them twice a day. Water was available *ad libitum* via an automatic distributor. A total of 96 lambs and female mixed, were used during the test. They were Romanov breed, Romanov X Rouge de l'Ouest and Romanov X Ile de France. They were followed for 24 h after birth up to four weeks of life.

Diets

Two milk replacer powders (about 98% DM) were used: a standard milk (ovicap lysar), additional milk containing half milk powder plus egg powder (yellowy like yolk) (ovicap egg lysar). The milk contain about 60% of skimmed milk powder, oils and fats products and by-products of cereal grains, minerals and vitamins (A, D_3, E, B_1, K_3 and C). The egg powder was distributed to 20 % with the remainder (80%). The formulation of experimental lamb milk replacer used was: 16 g of milk powder diluted into 100 g of water and the lambs were fed *ad libitum.*

Allotment of animals

A meal of bovine colostrum was administered to all the lambs before the lot. They were then randomly assigned into 10 groups, chronologically as birth. The 96 lambs were used in 10 floors covered with straw (litter) and isolated from any air currents. During the first 2 days, the weakest lambs were helped to drink with bottles. They are fast and familiar to use the bucket feeder equipped with multiple teats. Continuous monitoring feeders day and night permitted to avoid another failure of the milk food. Thereafter, the feeders were supplied twice a day at 8 AM and 17 PM. The different diets were prepared in tanks equipped with an electric mixer with water at a temperature of about 38 °C and distributed *ad libitum.* The amounts offered were adjusted daily based on refusal of the day to avoid too much waste. The rejected quantities were weighed in the morning and then carefully recorded on tracking sheets maintained on panels attached to each box. Feeders were cleaned daily to minimize microbial growth. The litter was renewed 3 times a week for the convenience of lambs and optimal improvement of experimental conditions.

Zoo technique measured parameters

The lambs were followed for 4 weeks, given the maximum weight required for sale. Once a week, and at the same time, they were weighed. Calculations were performed to determine the weights to age type of groups, especially at 7, 14, 21 and 28 days. The amounts of reconstituted milk and daily consumed were identified and brought back in g of powder for each batch and per kg of life weight for the considered period. The consumption index was calculated for each batch. Every 2 weeks, blood tests samples in tubes containing a drop of heparin were realized for the measurement of the hematocrit of lambs (the study protocol).

Statistical analysis

The obtained data for the evaluation of body weight, weight gain, milk intake, feed efficiency and hematocrit of lambs of different batches were subjected to analysis of variance, using Statview version 5.0, SAS Institute Inc. (USA) for differences between lots.

Results

Health status, appetite and consumption

During the experiment, 9 lambs died in the ovicap lysar batch and 5 in the lysar and-egg group. These animals were replaced when it was possible, that is to say, when death intervened in the first 2 days. Lambs appetite in both groups was satisfactory from the beginning to the end of the test. Digestive problems with constipation and flatulence, as well as hair falls were recorded in lambs subjected to the lysar egg powder regime.

Live weight of lambs

Analysis of variance (ANOVA) showed no fortunately significant difference between the birth weights of lambs submitted to the 2 diets, indicating, despite randomization, good distribution of lambs in batches. From the first to the fourth week of life, there was a significant difference ($p < 0.01$ and $p < 0.001$) (Figure 1) among the weight gain of lambs fed ovicap lysar and those who received the food containing the egg powder. This last batch presented a relatively low average increases. In the first week, the weight difference was significant with the values of 4215±326 g against

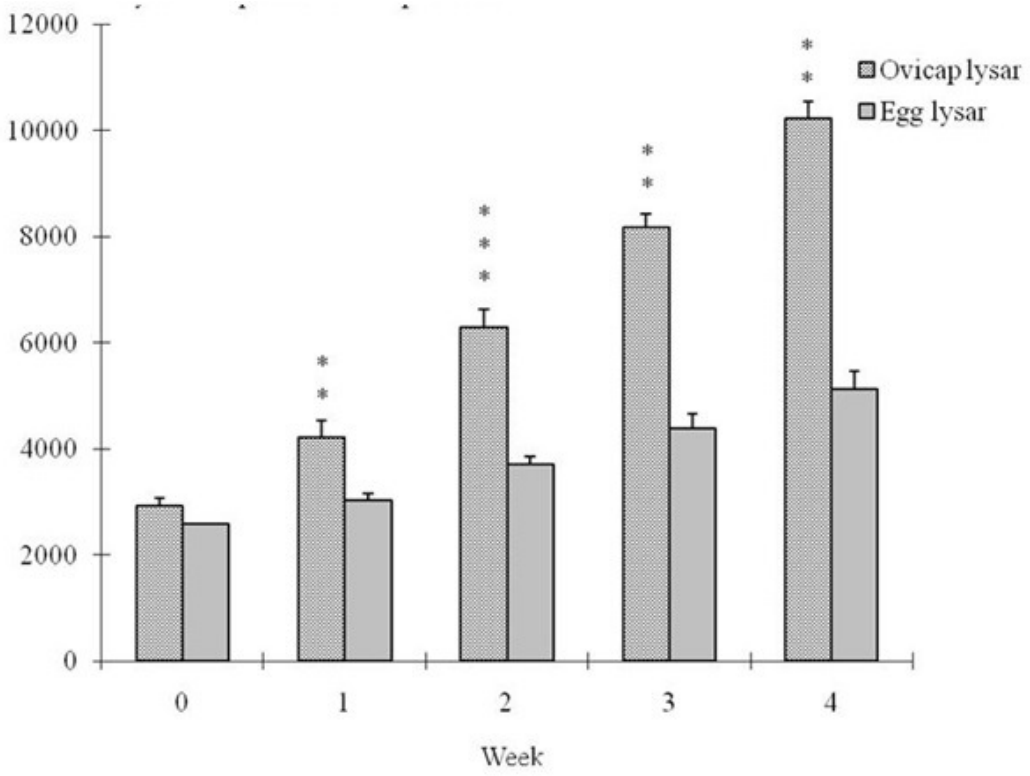

Figure 1. Evolution of body weight of lambs fed Ovicap lysar and egg lysar.** p<0.01; *** p<0.001.

3020±143 g, respectively for ovicap lysar group and the egg powder batch. Then, the differences widened further until the end of the experiment.

Weight gain of lambs

The evaluation of the average daily weight gain of lambs in both regimes during the 4 weeks will follow along with the live weight. Weight gain obtained with the ovicap lysar batch is significantly higher ($p < 0.001$) than that measured with egg food one during the 4 weeks (Figure 2). Lambs fed ovicap lysar had gain of 2054±278 g in the fourth week, a value equivalent to three times that reported in lambs who consumed the food egg and whose earnings barely exceeded 731±132 g at the same time.

Consumption of milk powder

The average weekly consumption of milk powder for both plans is increasing with age for the lot fed the ovicap lysar during the 4 periods (Figure 3). However, this growth remains relatively low and significantly lower ($p < 0.01$ and $p < 0.001$) for the lot plan egg lysar that has a value of 1584±221g in the fourth week, approaching that of 1447 ± 95 g, corresponding to ovicap lot consumption in the first week. Powder consumption reported per kg of body weight (Figure 4) is similar for both diets 1, 3 and 4 weeks. However, it is significantly higher ($p<0.05$) in the second week for the egg diet, with an average of 0.38 ±0.02 g against 0.34±0.03 g for ovicap lysar.

Feed conversion ration (FCR)

The FCR is expressed as the ratio between the amount of food consumed during a specific period and weight gain recorded during this time. The index of consumption of animals subjected to ovicap regime is significantly lower than those of the egg diet (Figure 5). In fact, one week of life, it was already observed for this last batch, a consumption index of 2.3±0.5 against 1.13±1.17 for the lot fed ovicap lysar.

Hematocrit

At birth, the lambs of the 2 batches showed an equivalent hematocrit level, with values of 41.00±5.98 and 41.00±6.15, for those received ovicap diet and egg respectively (Figure 6). One difference is then recorded at 2 and 4 weeks, resulting in a significantly lower

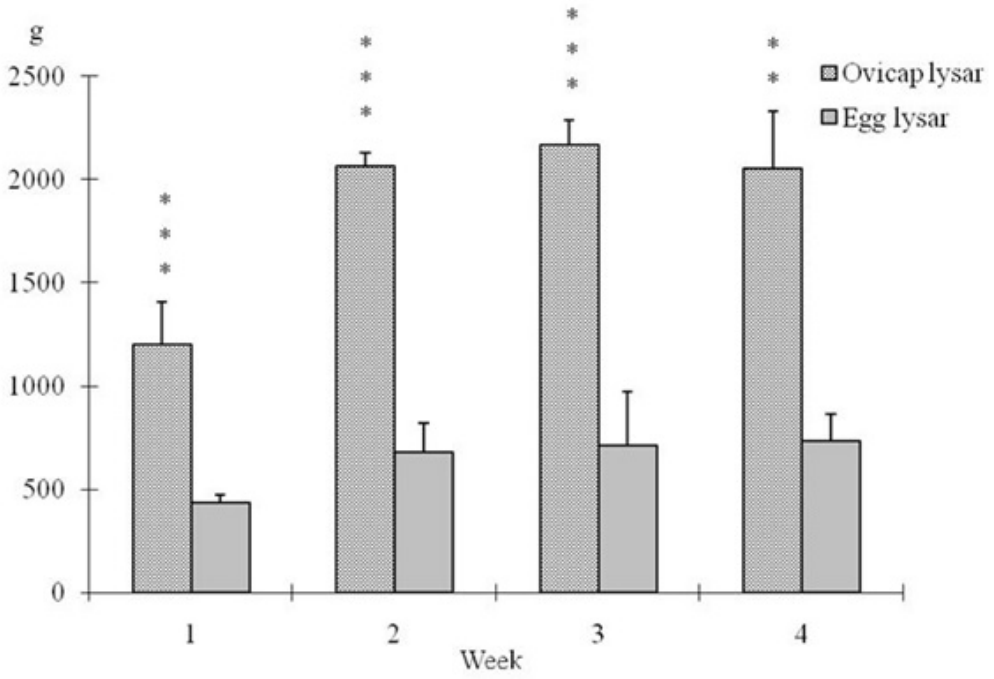

Figure 2. Evolution of the average weight of lamb fed Ovicap lysar and egg lysar. *** p<0.001.

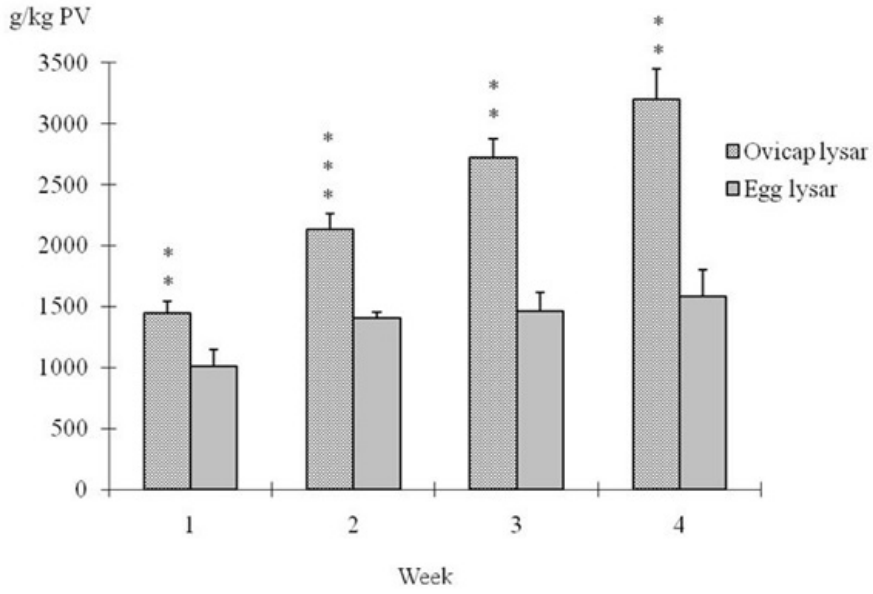

Figure 3. Evolution of milk powder consumption by lambs fed ovicap lysar and egg lysar. ** p<0.01,*** p< 0.001.

hematocrit level (p<0.001) for the egg diet.

DISCUSSION

At birth, the infant ruminant is more like a monogastric animal in its digestive functions. Because of these differences, the diet of adult ruminants is not compatible with the digestive system of pre-ruminants. Therefore feeding management of pre-ruminants needs special attention with reference to the type of food to be given and the way they are fed.

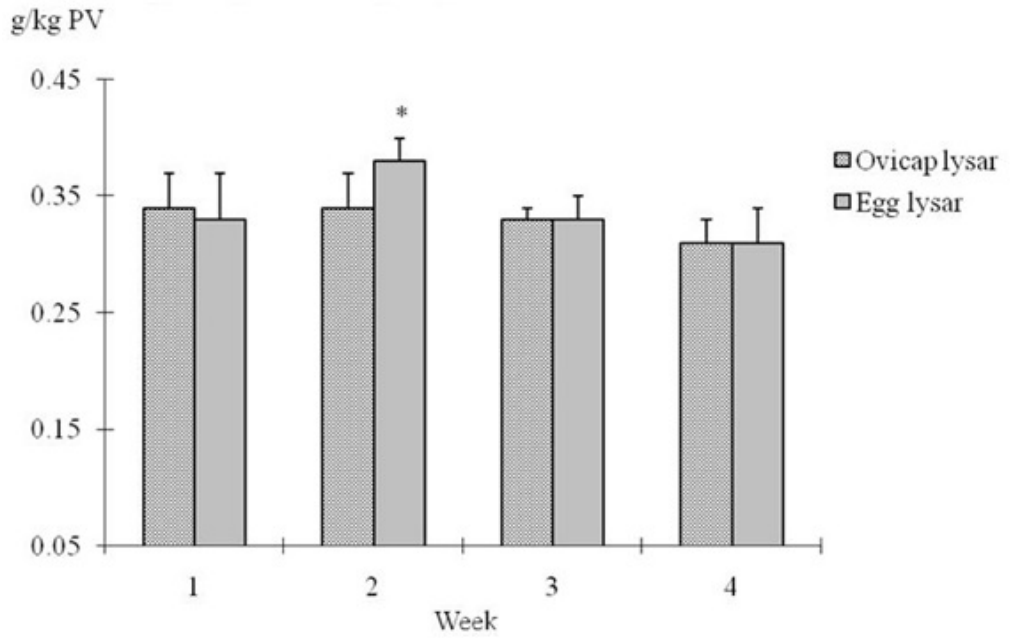

Figure 4. Evolution of milk powder consumption per kg of body weight depending on lambs age. * p< 0.05.

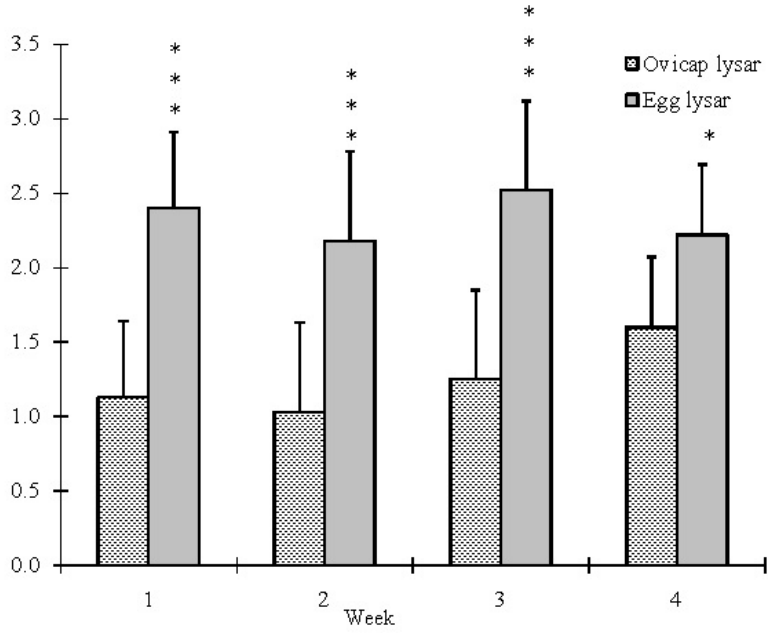

Figure 5. Evolution of feed efficiency of lambs fed ovicap lysar and egg lysar *** p <0.001.

Furthermore, the high index of consumption for the egg diet lambs group sign bad digestive and / or metabolic utilization of this milk-egg compound. Indeed, it has been observed that consumption per kg of body weight was similar for lambs subjected to 2 regimes during most of the monitoring period. Spray dried whole egg (SDWE) is

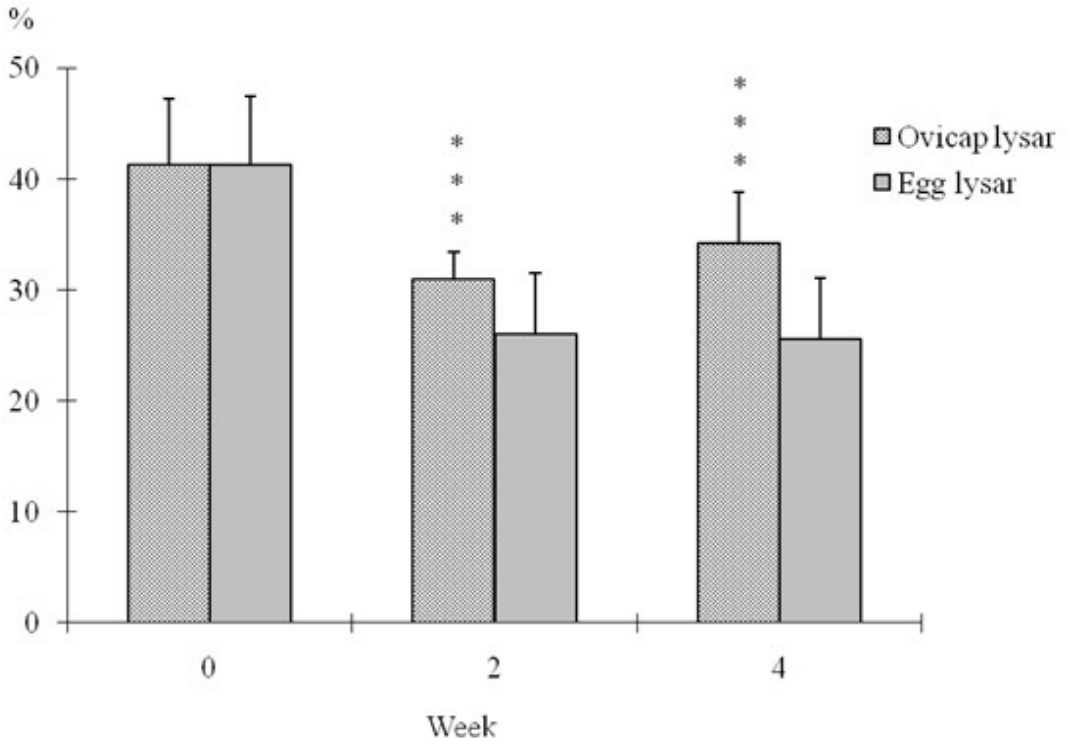

Figure 6. Evolution of hematocrit of lambs fed ovicap lysar and egg lysar. *** p<0.001.

a high quality alternative feed ingredient that contains significant amount of fat and protein. While protein is of high biological value, the fat contains lecithin which can give emulsifying properties to milk replacers if included as an ingredient. Although non-edible SDWE is produced in significant quantities by the egg processing industry, the limitation to its use in animal feeds is the presence of anti-nutritional proteins, including protease inhibitors and avidin, which irreversibly binds biotin.

Inclusion of SDWE at 10 percent in milk replacers as a substitute for whey protein concentrate reduced growth performance of pre-ruminant calves in spite of supplementing biotin to overcome the effect of avidin and balancing of milk replacer for amino acids lysine, methionine, threonine and leucine (Quigley, 2002).

The disturbances observed by joining observations related in the literature on the use of eggs for human consumption (Iyngkaran et al*.,* 1982), Hoffman, 1983); De Maat-Bleeker et al., 1985) and animal (Loosli, 1961; Brown and Varnell, 1962; Thapon, 1981). The likely scenario for an explanation of these disturbances is their allocation to factors contained in the egg white: ovomucoid and ovoinhibitor are indeed able to inhibit some proteolytic enzymes as trypsin and chymotrypsin (Thapon, 1981; Goodale et al*.,* 1988, Rannou, 2015). Obviously, this has a corollary decline in digestibility of the product. A similar remark was also made after a study of calves fed milk containing 5 % of egg powder (Spencer Food Industrial, unconfirmed data). Few studies are available on the topic lamb and few data exist in the calf. Roy (1956) mentioned the possibility of keeping alive calves with eggs and water with inclusion of liquid egg as a substitute for protein from milk based by-products at a level of 5 percent in the milk replacer (13.5 percent of milk-based protein) resulted in higher weight gain than in calves fed all-milk protein, but as the level of liquid egg increased beyond 10 percent in milk replacer (replacing 27 percent of milk-based protein), affected weight gain adversely. These findings indicate that liquid egg can be an effective alternative protein source in milk replacers when fed at levels up to 10 percent of the diet in a conventional feeding program of 0.45 kg per head per day (Touchette et al., 2003).

Observations were later compromised by those of Loosli (1961), who questioned the nutritional value of eggs for young calves. Brown and Varnell (1962), experiments finally confirmed misuse of egg protein by breeding calf: by adding 2 eggs to a diet consisting of skim milk, these authors did not obtain differences in growth among the control and experimental lots. However, when they distributed eggs to the calves (up to 40 eggs per day and per calf) just after taking colostrum, they observed a weight loss of 5 kg in 2 weeks, compared to the control group. These results support the activity, in the digestive tract, of the milk replacer containing egg powder.

In a second step, metabolic problems were suspected: the lambs submitted to the egg diet consumed quantitatively less food than the ovicap bach (Figure 3) with, obviously, non-compensation on the weight gain (Figure 2).

It is also interesting to discuss the implication of the combined effect of avidin, a heat-resistant protein in the egg white, which, by binding very tightly (non-covalently relation) to biotin, vitamin H or B_8, and prevents the absorption of the latter in the intestine (Thapon, 1992). Avidin, a heterogeneous fraction represents only 0.05 % of total egg protein, but it has high basic level 9.5 and binds biotin very specifically and tightly (Sugino et al., 1997, Thapon, 1992, Said, 2002). Its activities will be based on the incorporation of egg powder in the feed rate.

As with other alternatives protein, the physical and / or chemical treatments that the milk food containing egg suffered during the process of its manufacture and packaging can play an important role in the digestibility of the constituent proteins.

Processing technology for the production of breast milk that contains the egg is unknown; we only know that formulators are generally more interested in the bacteriological quality of the finished product. We then admit that metabolic disturbances generated by the egg food in lambs can be attributed to the manufacturing process. Indeed, we know that the powder was prepared from whole raw eggs without shell.

The avidin from the egg whites could be responsible for a defense mechanism inhibiting the growth of bacteria that synthesize biotin (Said, 2002). When the eggs are cooked, avidin is denatured (and therefore inactivated) as are other proteins in egg white (Hoffmann, 1971; Lehninger et al., 1993, Said, 2002). The avidin activity directly affects the biotin metabolism which is in turn disrupted (Munnich et al., 1987).

Finally, lambs hematocrit was measured. The level is normal for the 2 lots at birth. Then, the fall observed in lambs which consumed the egg powder is very pronounced in the second and fourth week.

This could be explained by the presence of conalbumin or ovotransferrin of the endosperm, a glycoprotein that can fix very efficiently di or trivalent metal ions; do the role of transporter, microbial agent (Al-Mashikhi and Nakai, 1987), as Fe^{++}, Cu^{++}, Zn^{++}, Al^{+++}) to form stable complexes colored or not (red with iron), highly resistant to thermal denaturation and enzymatic attack.

The other co-involved substance is phosvitin, another glycoprotein from yolk, which can form soluble complexes with Ca^{++} and Mg^{++} ions at low ionic strength (Sugino et al., 1997; Samaraweera, 2011). It also regulates very efficiently, Fe^{+++} ions, the remaining complex staying soluble as iron is not in excess. Thus, this protein would be a carrier of iron in the egg yolk (Thapon, 1981). The main results show the milk replacer containing egg powder causes physiological disturbances in lambs. A significant proportion of dietary protein enters the small intestine shortly form or not degraded and are likely to lead to physiological disorders at this level Caugant (1993). These assumptions may be made in the case of egg protein. Indeed, Brown and Varnell (1962) concluded the growth in veal calves fed a diet based on egg showed the pre ruminant is unable to properly use the protein product (Spencer Food Industrial, Roger Christian from Bridel industry, unconfirmed data).

However, to determine precisely the reasons for the poor growth performance of lambs, it should be necessary to study the digestibility of protein in milk containing egg powder at different levels of the digestive tract and with several levels of incorporation to measure animal performance. With A level of 5 % showed a difference in 25-30 weeks old calves fattening (Spencer Food Industrial In the pre ruminant calves for instance, there is a specific level of incorporation of alternative protein (about 31 % for soybeans) for satisfactory growth (Nunes Do Prado et al., 1988; Caugant, 1993). It should be suitable to guide future research on egg powder on aspects of incorporation - digestive efficiency.

Conclusion

In view of the obtained results, the milk replacer containing 20 % of egg powder appears to be a very bad milk replacer and is not at all suitable for feeding pre ruminant lamb. Further studies on digestibility of milk replacers based on raw egg and cooked differently and deserve to be treated firms, also with different levels of incorporation to determine the mechanisms involved in physiological disorders observed. This could help to identify the exact causes of growth inhibition in lambs that have been subjected to this diet containing egg and for which deficiency symptoms have also been found in other animals.

ACKNOWLEDGMENTS

The authors thank the industries Néolait and Valoroeuf for their collaboration. Their grateful to Mr Roger Christian (Besnier-Bridel, Rennes) and to Jean Louis Thapon (ENSA Rennes) for their contribution to literature, as well. They thank Agnès Cotiniaux, Miss Isabelle Kauffer, Mr Jacques Lareynie, Jean Noël Nouchet† and Henri Flageul for their valuable contribution during the experiment.

AUTHORS' DECLARATION

We declare that this study is an original research by our research team and we agree to publish it in the journal.

REFERENCES

Abeyrathne EDNS, Lee HY, Ahn DU (2013). Egg white proteins and their potential use in food processing or as nutraceutical and pharmaceutical agents- A review. Poultry Science Association Inc. Download fromhttp://ps.oxfordjournals.org by guest on May 17, 2016, p. 3292-3299.

Al-Mashikhi SA, Nakai N (1987). Separation of ovotransferrin form egg white by immobilized metal affinity chromatography. Agric. Biol. Chem. 51:2881–2887. CrossRefWeb of Science Google Scholar.

Bell DD., Patterson PH., Koelkebeck KW., Anderson KE., Darre MJ., Carey JB., Kuney DR., Zeidler G: Egg marketing in national supermarkets: egg quality-part 1. *Poultry Sci.,* 2001; 80, (4), 383-389.

Brown DC, Varnell TR (1962). Value of raw eggs in the diet of the young calf. J. Dairy Sci. XIV (11): 1394-1396.

Caugant I (1993). Gastric and intestinal digestion of dairy and vegetable proteins in the pre ruminant calves: studies *in vivo* and *in vitro*. PhD. Thesis. ENSAR. 188 p, FRANCE.

De Maat-Bleeker F, Van Dijk AG, Berrens L (1985). Allergy to egg yolk possibly induced by sensitization to bird serum antigens. Annal Allergy, 54: 245-248.

Goodale RL, Liener IE, Desmuskh A, Frick T, Satterberg T, Ward G, Borner JW (1988). Do trypsin inhibitors affect feedback control of human pancreatic secretion? Dig. Dis. Sci. 30: 972.

Hara-Kudo Y, Sakakibara Y, Konuma H, Sawada T, Kumagai S (2001). Laying season and egg shell cracks on the growth of salmonella enteritis in the egg albumen during storage. *J. Food Prot,* 64 (8): 1134-1137.

Hill TM, Aldrich MJ, Proeschel AJ, Schlotterbeck RL (2000). Feeding neonatal calves milk replacers containing egg proteins. *J. Dairy. Sci.* (Suppl. 1) 84: 265.

Hoffmann DR (1983). Immunochemical identification of the allergens in egg white. J. Allergy Clin. Immunol. (71): 481-486.

Hoffmann F (1971). Compendium des vitamines. La Roche & Co., Basel SWITZERLAND SA. 154 pages.

Iyngkaran N, Abidin Z, Meng LL, Yadav M (1982). Egg-protein-induced villous atrophy. J. Pediatric Gastroenterol. Nutr. (1): 29-33.

Kellogg DV, Johnson ZB, Lesmeister KE, Anschutz KS (2001). Growth of calves fed milk replacer contained dried egg product. *Arkansas Agric. Exp. Stn. Res. Ser.* 478: 149-154.

Kovacs-Nolan JKN, Phillips M, Mine Y (2005). Advances in the value of eggs and egg components for human health. J. Agric. Food Chem. 53: 8421-8431.

Lehninger AL, Nelson DL, Cox MM (1993). Principles of Biochemistry. 2nd Ed. Medecine-Sciences Flammarion. Worths Publishers, New York (USA). 1035 pages.

Loosli JK (1961). Questions from Dairymen. Hoard's Dairyman, April 25, p 424.

Munnich A, Ogier H, Saudubray JM (1987). Les vitamins. Aspects métaboliques, génétiques, nutritionnels et thérapeutiques, Editions Masson, 1987.

Nau F, Floury J, Hayo van der Werf, Le Minous AE (2016). Les œufs et les ovo produits dans l'alimentation des Français. *Cahiers de Nutrition et de Diététique*, Volume 51, Issue 3, Pages 147-156

Nau F. (1987). Synthèse bibliographique. Le jaune d'œuf, ENSA, INRA, FRANCE.

Nunes Do Prado I, Toullec R, Lalles JP, Gueguen J, Hingand L, Guilloteau P (1988). Digestion of pea protein and soy in the pre ruminant calves. I. Circulating levels of nutrients, antibodies and intestinal permeability to macromolecules training. Reprod. Nutr. Develop. 29: 413-424.

Quigley III JD, Jaynes CA, Mille ML, Shamus E, Chester-Jones GD, Marx GD, Allen DM (2000). Effects of hydrolyzed spray dried red blood cells in milk replacer on calf intake, body weight gain and efficiency. *J. Dairy Sci.* 83: 788- 794.

Quigley III JD (2002). Effects of spray-dried whole egg and biotin in calf milk replacer. *J. Dairy. Sci.* 85: 198-203.

Rannou C, Queveau D, Beaumal V, David Briand E, Le Borgne C, Meynier A, Anton M, Prost C, Schuck P, Loisel C (2015). Yolk powders. J. Food Eng. 154: 58-68.

Roy JHB (1956). The calf. Its management. Feeding and health. Farmer and Stock-breeder Publications, Ltd., London (ENGLAND).

Said HM (2002). Biotin: the forgotten vitamin. Am J Clin Nutr February 2002 75: 179-180.

Samaraweera H, Zhang Wan-gang, Joo Lee E, Ahn DU (2011). Egg Yolk Phosvitin and Functional Phosphopeptides—Review Vol. 76, Nr. 7, 2011 Journal of Food Science.

Sauveur B (1988). Reproduction des volailles et production d'œufs. INRA. Paris, Editions Quae. 449 pages.

Scott TA, Tomkins T, Vermeire D, Keith NK (1999). Evaluation of alternative protein milk replacers on growth and health of Holstein heifer calves. *J. Dairy Sci.* 82 (supp. 1): 46.

Sugino H, Nitoda T, Juneja LR (1997). General chemical composition of hen eggs. In: Yammamoti T, Juneja LR, Hatta H, Kim M, editors. Hen eggs: Their basic and applied science. Boca Raton: CRC Press.; pp. 13-24.

Tekinsen OC, Çelik C (1995). Egg. Selçuk Uni. Vet. Fac. Press. Konya, TURKEY; 1995; 31, 3-17.

Thapon JL (1981). Effets de divers facteurs sur les propriétés physico-chimiques et fonctionnelles du blanc d'œuf. Ph D. Thesis, Université de Rennes 1 (FRANCE).

Thapon JL (1992). Science et Technologie de l'œuf, ENSA Rennes, (FRANCE), 29 pages.

Tood EC (1996): Risk assessment of use of cracked eggs in Canada. *Int. J. Food Microbiol,* 1996; 30 (1-2), 125-143.

Touchette KJ, O'Brien ML, Coalson JA (2003). Liquid egg as an alternative protein source in calf milk replacers. J. Dairy Sci. 86: 2622–2628.

Toullec R (1988). Power of veal calves. In: R. JARRIGE (Ed). Feeding cattle, sheep and goats. INRA FRANCE, 471 p.

Yamamoto T, Juneja LR, Hatta H, Kim M (1997). Hen eggs: *Their basic and applied science. CRC Press, New York,* 1997; 15-28.