Use of clay as a growth promoter and rumen modifier : A Review

Kahouli, A[1]
[1]Institute of Veterinary and Agronomic Sciences, University of Batna 1, 05000 Batna, Algeria ;
*Correspondance : ab.kahouli@gmail.com

Abstract

The main limiting factor of the optimal expression of animal genetic potential is the nutritional supply. The intensification and industrialization of livestock puts the animal under stressful conditions, and obliges the perpetual and increased use of concentrated feeds with the increasing use of nutritional additives who have a negative image in consumers. In this respects, the orientation towards more artisanal organic production has become an obligation in the breeding sector. This concerns the elimination of any chemical substance and antibiotics in this field by derogating to a new alternatives to improve animal performances. Clay, a natural product, cheap and very abundant has been the subject of several scientific work to test its usefulness as a growth factor in animals including the category of ruminants. In this case, we will carry out a bibliographic analysis to put into effect the state of knowledge in this axis.

Keywords : additives, antibiotics, environment, performances, ruminants, welfare

Introduction

The main limiting factor of the optimal expression of the animal genetic potential is the nutritional supply. In addition, the intensification and industrialization of livestock puts the animal under stressful conditions, and obliges the perpetual and increased use of concentrated feeds with the increasing use of nutritional additives in order to improve food utilization, keep a good general state of animal health, and mitigate the environmental impact of livestock (Alloui, 2011 ; Peterson, 2012 ; Cuvelier *et al.*, 2015 ; Begum *et al.*, 2016). However, the use of feed additives still has a negative image among consumers and even farmers who do not cease to wonder about the safety of these additives including antibiotics and their ban around the world, this prompted more and more the use of artisanal production and foods with the biological label considered healthier (Claude, 2002 ; Pou *et al.*, 2017). In this respect, clay has been proven to be effective as a growth promoting additive to alternate drugs, which is what we are going to show in this review.

Geophagy

Geophagy is the deliberate and regular consumption by humans and animals of earthy materials such as soils, clays and associated mineral substances (Wilson, 2003). This behavior has been recorded by anthropologists since prehistoric circumstances (Williams and Hillier, 2014). Ferrell (2008) and Bonglaisin (2011) say that the consumption of earth and especially clay is a worldwide practice, associated with medicinal (antidiarrheal) and spiritual purposes in some cultures around the world. The legends associated with the healing powers of Chimayo Clay, New Mexico, are an excellent example of the roots of geophagy (Ferrell, 2008), however, Williams and Hillier (2014) reports that the medicinal uses of clays have been described in antiquity by Greek philosopher Aristotle

(4^{th} century BC), by Pliny the Elder and Dioscorides (1^{st} century AD) and in the writings of Galen of Pergamon (2^{th} century AD) where the clay is transformed into small slices and used remedy against a variety of ailments and poisons. In this sense, currently some pharmaceutical products are made from clay to treat digestive disorders include Smecta, Bedelix and Actapulgite (Ouachem and Soltane 2009).

Geophagy does not exist only in humans, but it can occur in animals as long as they are wild or domestic (Herlin and Andersson, 1996 ; Mahaney and Krishnamani, 2000 ; Trckova *et al.,* 2004) because of the innate ability of the animal to explore and taste at the chemically hostile environment according to Mahaney and Krishnamani (2000). In addition, ingestion of clay is considered to be natural in animals, considering that agricultural soils often contain a clay fraction (Duval, 1993 and Bonglaisin, 2011). In this sense, scientifics (Herlin and Andersson, 1996 ; Ouachem *et al.*, 2005 ; Ouachem and Soltane, 2009) explain that on pasture, animals can ingest up to 14% of the total dry matter (DM) ingested as much as it is adhered to the vegetation, this is not specific to ruminants since pigs eat naturally and in large quantities of soil, also for backyard poultry which ingest quantities of clay, which adheres to the seeds and soil.
Therefor, geophagy has been studied by anthropologists, geologists, nutritionists and ecologists in traditional and current cultures around the world (Bonglaisin, 2011). To explain this behavior, much hypotheses have been put forward, therfore according to (Mahaney and Krishnamani, 2000 ; Wilson, 2003 ; Williams and Hillier, 2014) these hypotheses can be grouped into 3 categories :

- Geophagy can relieve gastrointestinal disorders (antidiarrheal, detoxification and regulation of the pH of the digestive tract);
- Nutritional mineral supplementation ;
- It can also be used as food for famine, to satisfy sensory organs or to have no meaning other than a simple behavioral tradition.

Clay and the digestive process

1. Effects on the ruminal ecosystem

Ruminants have a unique digestive system. The fermentations generated by the microbiota that swarm there provide it with proteins and amino acids. The by-products of these fermentations are mainly volatil fatty acids (VFA), and ammonia ($N\text{-}NH_3$). Good nutritional sources for the animal's metabolism, however, the presence in excess of one or the other is toxic. Being the precursor parameter of ruminal fermentations, the pH is buffered by saliva containing sodium bicarbonate and potassium bicarbonate (Peterson, 2012).

Previously, Murray *et al.* (1990) and Fenn and leng (1990) found that the use of bentonite influences the ruminal ecosystem by stabilizing pH, increasing the density of the protozoan population and the molar concentration of VFA in the rumen. Right after, Wallace and Newbold (1991) supports these results, they find that the addition of (2gr/day) of bentonit in a synthetic ruminal medium improves the stability of the ecosystem by reducing the acidity, reducing the concentration of $N\text{-}NH_3$, and by improving the bioprocesses of fermentations followed by an increase in the molar concentration of VFA’s. They also claimed that the clay seems to significantly affect the ruminal microbiota, following to the increase of the bacterial mass (+33%) recorded in the experimental medium compared to the control, in particular that of the cellulolytic bacteria, although it is toxic for the protozoa, the total number of protozoa including holotriches has decreased significantly (-68.75%) compared to the control, all the more, this has been consolidated by the results of (Abdullah *et al.*, 1995 ; Filya *et al.*, 1999 ; Forouzani *et al.*, 2004 ; Khalifeh *et al.*, 2012) using another type of clay. according to authors, this has been explained by the inhibition of the locomotive system of these microbes by reducing their activity especially the predation of bacteria which is advantageous for the animal, being that this act is considered a loss of protein and energy rewarded commonly by the deamination of proteins. In fact, the protozoa are hydrogen producers because they favor the production of the precursor butyric acid of this element (Doreau *et al.,* 2011), and thus their suppression makes it possible to attenuate the methanogenesis.

Subsequently, several results supported these findings. In this regard, (Ouachem and Nouicer, 2006 ; Laibi *et al*., 2015 ; Sulzberger, 2016 ; Dal-Pozzo *et al.,* 2016) reported the same shape of rumen parameters in the presence of clay. Besides, Abdl-Rahman (2010) adds that clay can reduce the production of CH_4 by the more hydrogen methane precursor following the accelerated production of VFA (Doreau *et al.,* 2001 ; Kardaya *et al.,* 2012). In fact, the authors attribute the beneficial effect of clay to its chemical and physical properties. By its CEC, the clay can exchange its cations with others which are in the host medium, it can also exchange its cations in the ruminal medium with the protons (H^+) of the medium by attenuating the acidity, some minerals enriching the medium in others very useful for digestion and microbial growth in, ammonia ions which constitutes nitrogen savings.

On the other hand, previous and even recent studies, whether *in-vivo* or *in-vitro*, carried out on sheep, goats and even cattle such as those of (Bosi *et al.,* 2002 ; Erwanto *et al.,* 2011 ; Jiang *et al.,* 2014 ; Antonelo, 2017) oppose what has been cited before about the effect of clay in the ruminal ecosystem. These studies reveal that the addition of clay had no significantly significant effect on the ruminal environment or on its parameters, which contradicts the findings.

2. Effects on the nutritional dynamics

As discussed just above (see section : effect on the ruminal ecosystem) the incorporation of clay bring changes in rumen parameters. These changes are able to automatically impact nutritional dynamics throughout the digestive tract. In other words, the stabilization and alkalinization of the ruminal pH changes the structure of the rumen population and the pace of fermentations that take place in it, with an increase in the total production of VFA’s, although it tends towards a higher production of propionic acid stimulating neoglucogenesis at the expense of acetic acid and butyric acid. This reflects good ruminal digestion, as a consequence to lower alimentary passage due to osmotic potential of clay. this is able to expose the plant particles to intense microbial digestive activity knowing that clay can enriches rumen with mineral elements as Ca and Mg good for microbiogenesis and adhesion of bacteria to these particles (Johnson *et al*., 1988; Ouachem and Nouicer, 2006; Abld-Rahman, 2010; Laibi *et al*., 2015). However, in other studies, there was a lack of effects of clay on the ingestibility and at times a simple numerical increase (Ivan *et al.,* 1992 ; Berthiaume *et al*., 2007 ; Ibrahim, 2012 ; Ortiz *et al.,* 2016), unlike at (Sadeghi and Shawrang, 2006 ; Stojković *et al.,* 2005 ; Oka *et al.,* 2015) which indicate a significant increase in the dry matter (DM) ingestion of under the effect of the zeolite. Moreover, Sadeghi and Shawrang (2006) explain that by the increase in the consumption of water in the presence clay in order to respect the osmolarity dormancy because of the high presence of the minerals provided by the zeolite, which increases the food passage and hence the ingestibility.

In addition, the improvement of digestive capacities has also been consolidated by several results of scientic works (Jacques *et al*., 1986 ; Sadeghi and Shawrang, 2006 ; Stojković *et al*., 2012 and Antonelo *et al*., 2017) which show that clay improves the digestibility of DM, organic matter (OM), total protein and fiber in the rumen following an improvement in microbial activity, while other studies contradict it namely, Berthiaume *et al.* (2007) which found no significant results of the use of clay on digestibility or similarly to Johnson *et al.* (1988) and Ortiz *et al.* (2016) which report that the use of clay has a negative impact on feed efficiency by lowering the digestibility of DM, OM, fiber and total protein. These improvements have another benefit on the nitrogen balance (Ivan *et al.,* 1992 ; Mohsen and Tawfik, 2002) and energy through the increase of the net energy available for the animal following the improvement of the digestibility of the OM and the carbohydrates, and the reduction depletion of body reserves following the reduction of lipid oxidation according to (Katsoulos *et al.*, 2006 ; Karatzia *et al.,* 2013 ; Uyarlar *et al.*, 2018), in this sense, is added the reduction in the production of acetic acid in particular and the increase of the production of VFA's including propionic acid in general with an acceleration of biohydrogenation, which does not leave enough substrates for methanogenesis (Chouinard, 2000 ; Kardaya *et al.*, 2012 ; Tate *et al.,* 2015) since it constitutes a loss of 10% or even more digestible energy (Sauvant 1992 ; McDonald *et al.*, 2002 ; Jouany and Thivend 2008). This is common with the reduction of protozoa in the rumen under the effect of clay according to several studies, which are the main producers of methane. In fact, the reduction of the protozoan population has a nutritional benefit, being the predators of bacteria which reduces a part of the microbial proteins available to the body (Wallace and Newbold 1991 ; Abdulah *et al.*, 1995 ; Forouzani *et al.*, 2004 ; Popova *et al.,* 2011), they ingest the majority of proteins that enter the rumen (75% of protein ingested by the animal are degraded by the reticulorumen microflora according to O'Connell and Fox (2001)), in this case, their elimination constitutes a protein gain and increases the flow of proteins passing to the intestine (Ivan *et al.*, 1992 ; Bosi *et al.*, 2002 ; Doreau *et al.*, 2011).

Similarly, the decrease of N-NH_3 in the presence of clay is itself a nutritional gain. It allows to save nitrogen in pure nitrogen regimes by capturing non-protein nitrogen either between its leaves or adsorbent and consequently it reduces ammoniogenesis which in its excess becomes very toxic (Ouachem and Nouicer, 2006 ; Erwanto *et al.*, 2011 ; Goodarzi and Nanekarani, 2012 ; Laibi *et al.*, 2015). In this case, Khalifeh *et al.* (2012) adds that clay can promote protein supply to the intestine, it can encapsulate proteins and amino acids by avoiding the digestive attack of microbes.

3. Effects on the biochemical profile

The biochemical profile is the reflector of the nutritional status of animals. The changes that can happen there seem to be nutritional or physiological. In this sense, the use of nutritional additives is likely to influence the biochemical parameters proteinic, energetic, mineral and even hormonal. However, inconsistency in the results is observed in the literature, which is probably due to differences in animal species and even in breeds, the physiological stage of the experimental animals, the time of sampling and the food according to Toprak *et al.* (2016).

It should be noted that (Katsoulos *et al.*, 2006 ; Kardaya *et al.*, 2012 ; Ibrahim, 2012 ; Uyarlar *et al.*, 2018) agree that clay has no noticeable effect on the biochemical profile of ruminants.

On the other hand, (Katsoulos *et al.*, 2006 ; Toprak *et al.*, 2016 ; Karatzia *et al.*, 2013 ; Khachlouf *et al.*, 2019) report that the use of zeolite in dairy cows at the peripartum influences the biochemical profile. They reveal that serum glucose, ketones, free fatty acids, total proteins, calcium, magnesium, phosphate were influenced by the addition of clay. Higher blood sugar around calving in cows receiving clay and lower ketones and free fatty acids indicate that cows are in an optimal energy balance. As well, plasma calcium levels were higher in experimental cows around calving, which is due to the activation of homeostatic metabolism to protect the cow against hypocalcemia. In addition, the blood level of magnesium was lower in the cows receiving the clay which is explained according to the author by the adsorption of this element by the clay. As well, a depression in the serum phosphate level a week before calving compared to the control is according to the author caused by two kinds of phenomena, one is the strong circulation of the PTH (Para-Thyroid-Hormone) at this stage which consequently increases the phosphate secretion by the salivary and renal pathways, the other is the adsorption of the phosphate by the clay.

In addition, according their study, Mohri *et al.* (2008) indicate that the addition of clinoptilolite at a dose of 2% in colostrum and milk of newborn calves brings considerable changes in their blood profile, particularly with Fe, Ca, Mg, Na. The group receiving colostrum with clay had a higher plasma ferric concentration +51% ($p<0,05$) compared to the other groups, the calcium and sodium group was higher in the experimental calves +19% et +12% ($p<0,05$) than in the controls, whereas the phosphorus level was lower in the experimental groups compared to the control -15% ($p<0,05$) which is attributable to the cation exchange capacity of clinoptilolite which can serve as a reservoir of mineral elements. Ghaemnia *et al.* (2010) adds that the supplementation of the ration of Arabi sheep in Iran with (6 or 9%) zeolite significantly reduces the concentration of urea in the blood of the group receiving 9% of zeolite supporting the result of Mohsen and Tawfik (2002), they also reveal a numerical drop in blood glucose (-11% and -6%) in the two groups receiving 6-9% zeolite respectively relative to the control. This decrease is explained according to the author by the capacity of the clay to reduce the ammonia concentration and rumen VFAs as mentioned above which are precursors of uremia and blood glucose (see section : clay-rumen parameters). This contrasts with the findings of Filya *et al.* (1999) who find that the use of zeolite in fattening lambs induces a significant increase in uric and ammoniacal nitrogen in the blood.

Clay and health and animal welfare

According to Slamonva *et al.* (2011), clay minerals are important in many aspects. Their properties such as structure and chemical composition, type of exchangeable ions and particle size determine their various uses. The healing powers of clay have been known for centuries and are now rediscovered. The practice of consuming clay by animals in the wild for the detoxification of the body and the relief of gastrointestinal infections was well documented. Initially, clays were introduced into farm animal feed as pelleted feed binders and then used as feed additives to promote growth and animal health. The actual use of clay and clay minerals is directed to the production of selective sorbents applicable to human and veterinary medicine.

As previously discussed (see sections : effect on the ruminal ecosystem and Effect on the nutritional dynamics), the clay has been proven to stabilize the ruminal ecosystem by reducing the acidity following ingestion of the concentrate. to reduce the share of ammonia nitrogen produced in the rumen which is likely to prevent the animal from falling in the case of nutritional disorders such as acidosis and alkalosis and other ailments who succeed know ruminitis, laminitis, laborious breathing, etc. (Mullaert 2010 ; Peterson, 2012 ; Parmigiani *et al.*, 2013 ; Garzón *et al.*, 2017). The clay also makes it possible to enrich the food with the mineral elements necessary for the animal organism, in particular the major minerals such as Ca and Mg, by reducing the incidence of nutritional disorders such as hypocalcemia and hypomagnesemia especially. during périparturialle (Thilsing-Hansen *et al.*, 2002 ; Kastoulos *et al.*, 2005 ; Khachlouf *et al.*, 2019), allowing more a better kinetic of body reserves and avoid the females falling into the complicat ion nutritional périparturialles include the pregnancy toxemia in ewes and ketosis for cows milk, and avoid obstructed labor (Ilic *et al.*, 2007).

Accumulated evidence from preclinical and first trials in humans suggests that supplemental treatment with oral zeolite is associated with significant immunomodulatory effects that may improve the primary treatment of many immunodeficiency disorders (Ivkovic *et al.*, 2004). In animals, this is the same according to (Martin-Kleiner *et al.*, 2001 ; Andronikashvili *et al.*, 2009 ; Laurino and Palmieri 2015) by asserting the immunomodulatory capacity of clays. Pavelic *et al.* (2002) found that the use of zeolite in rats improves their immune system, causing inflammation in the place of application, which activates the macrophages and lymphatic cells responsible for the defense of the body. Natalija and Biljana (2007), also, Sadeghi and Shawrang (2008) agree that incorporation of clinoptilolite into calve's colostrum improves their defense system by increasing the uptake of immunoglobulins contained therein. Natalija and Biljana (2007) adds that clinoptilolite can protect and extend the lifespan of primary enterocytes that have the most immunoglobulin receptors compared to those that replace them, which subsequently increases the uptake of these defense proteins.

According to Vandiest (2010), diarrhea is a very common disorder especially in newborns and causes colossal losses and can even cause death of lambs. In lambs, it has several causes, it can be viral (rotavirus), bacterial (colibacillosis, enterotoxemia, coccidiosis, salmonellosis) fungal (cryptosporidiosis) or parasitic, or even food during the abrupt change of the weaning diet (Brugère-picoux, 2004 ; Vandiest, 2010). In this case, Norouzian *et al.* (2010) mentions that the use of clinoptilolite in lambs reduced the incidence of diarrhea by 16% and 18% in the presence of clay with doses of 1.5% and 3% respectively in comparison with the witness. This fits perfectly with the previous result of Stojkovićet *et al.* (2005). In addition, Sadeghi and Shawrang (2008) also Zarcula *et al.* (2010) adds that the incorporation of clinoptilolite in colostrum in new born calves improves their health status, this significantly reduces the intensity of diarrhea. Moreover, these authors cite that this result is explicable either by the retention of enterotoxigenic *Escherichia coli* thus limiting its binding to the receptors of the intestinal cell membrane, or, by the reduction of the alimentary passage, consequently its property of fluid retention absorbs water and suddenly the fascicles become stronger.

Clay can have an antibacterial action (Mahaney and Krishnamani, 2003). In fact, this depends largely on its mineralogical composition according to Slamova *et al.* (2011). Top and Ülkü (2004) indicates that clinoptilolite can be an effective and low-cost antibacterial, given its chemical composition and cation exchange selectivity. In addition, Zarcula *et al.* (2010) report that clay can reduce diarrhea in calves because it can retain the bacteria that causes them (*Escherichia coli*). Malachová *et al.* (2011) added as montmorillonite may be an antimicrobial (antibacterial and antifungal) effective, capable of carrying ions of metal with properties antibacterial and antifungal agents such as silver.

Mycotoxins are secondary metabolites of fungi such as *Aflatoxins* (AFM_1, AFB_1) and *Zearalenones spp* (ZEA) from genera *Aspergillus spp* and *Fusarium spp* respectively, they usually enter the body through fodder or food contaminated, harmful in an unimaginable way on animal health and zootechnical performance (Jacques *et al.*, 1986 ; Stojšić *et al.*, 2004 ; Pešev *et al.*, 2005 ; Mapham and Vorster, 2013). The majority of mycotoxins are resistant to degradation in the rumen, they can sometimes be asymptotic. The health complications caused by mycotoxins are of several kinds, they can cause intermittent diarrhea, abomasum displacement, ketosis, hepatic steatosis, placental retention, metritis, mastitis, etc. they can affect growth performance including reduction of ingestibility, deterioration of feed convertion ration (FCR), they can also influence the reproductive function of animals by reducing fertility, including the appearance of irregular estrus cycles, embryonic mortality and a drop in the design rate (Pešev *et al.*, 2005 ; Niderkorn *et al.*, 2007 ; Mapham and Vorster 2013).

Theoretically, certain additives are likely to act beneficially on the mycotoxins by holding them before they are absorbed in the digestive tract. In fact, clay is a potentially effective additive to these metabolites (Niderkorn *et al.*, 2007 ; Mapham and Vorster, 2013). The sequestering power varies and depends largely on the microstructure of clays (Spotti *et al.*, 2005 ; Katsoulos *et al.*, 2016). In an *in-vitro* study to quantify AFB1 aflatoxin sequestration by adding different types of clays, Spotti *et al.* (2005) found that bentonite and sepiolite had the best retention capacity by retaining the AFB1 at 100%, followed by zeolite retaining more than 90% of AFB11, and lastly clinoptilolite, which retains about 80% of AFB. This finding has been reinforced by other studies confirming that clay effectively retains mycotoxins and prevents them from being absorbed and prevents their adverse effects in animals, such as (Jaynes and Zartman 2011 ; Kazemi *et al.*, 2012 ; Katsoulos *et al.*, 2016 ; Chefchaou *et al*., 2019). In addition, Stojšić *et al.* (2004) and Stojković *et al.* (2005) adds that the use of zeolite eliminates residues of zearalenone from the liver, kidneys, and muscles in animals fed fodder contaminated with this mycotoxin.

Otherwise, certain pollutants such as nitrites and nitrates can have a devastating impact on the animal organism when they enter it. In this sense, on dairy cows watered with water contaminated with high doses and toxic nitrate, Kastoulos *et al.* (2015) found that the incorporation of clinoptilolite in the diet of these cows helps mitigate effectively the harmful effect of high doses of nitrates.

In addition, free radicals induce oxidative stress in the animal body when they are beyond their physiological threshold, in this case, causes economic losses due to damage of certain physiological functions that can achieve performance productive and reproductive animals (Zhong and Zhou, 2013). In this context, the use of clay can serve as a good antioxidant according to Laurino and Palmieri (2015). According to Wu *et al.* (2015), it can trap free radicals in its structure, inactivating and eliminating them. It can also delay the peroxidation of lipids and thus reduce the catalytic production of free radicals to protect the body against oxidative stress. In this sense, by conducting an experiment on dairy cows to quantify the effect of zeolite on their oxidative stress, Ipek *et al.* (2012) found that 2.5% of this clay in the total ration improves the oxidative status of these animals, by reducing lipid peroxidation to almost (20%) which confirms the antioxidant power of clays.

Clay and zootechnical performances

1. *Effects on growth performances*

In cows, Tabbaa (1999) found that, in the presence of clay, the growth performances showed a considerable improvement, the average daily gain (ADG) was significantly higher in the animals receiving the clay (+ 5.4%) of difference compared to witness what is the same but digital for the dry matter intake (DMI). This is consolidated by subsequent results, moreover Berthiaume *et al.*, (2007) reports the same trend of significant effects of clay on the growth performance of cattle. The latter found a significant increase of more than 41% of ADG, while for the DMI, a numerical increase of (+10%) in the experimental group compared to the control, as well, the FCR was numerically lower in the animals receiving the clay. which was well supported afterwards by the results of Pešev *et al.*, (2011). In this sense, Ural and Ural (2017) report similar results from the above reporting quite significant beneficial effects of the clay on the growth performance of calves with an improvement of more than (+17%) ADG which is also in agreement with results of (Zarcula *et al.*, 2010 ; Ural and Ural, 2017 ; Antonelo *et al.*, 2017). However, (Koknaroglu *et al.*, 2006 ; Oka *et al.*, 2015 ; Ortiz *et al.*, 2016) contradict all these observations by neglecting the effect of clay on this kind of performance.

When it comes to body condition score (BCS), the work of Karatzia *et al.* (2013) reveals that the use of clay is beneficial to maintain body reserves or even to restore them. They found that the BCS had a highly significant increase in the presence of clay, a superiority of more than 19% over those who did not receive it. All the more, around the calving, the cows suffered a fall of BCS, this fall was well pronounced and long in the control group compared to the experimental group. The authors explain this result by improving the energy status of cows under the effect of clay, visibly remarkable in the biochemical profile of animals where there was a significant difference in blood glucose and acetonemia. This is in close agreement with the results of (Parmigiani *et al.*, 2013 ; Garzón Prado *et al.*, 2017).

In goats, Mohsen and Tawfik (2002) indicates an improvement in the order of (+ 14.2%) and (+ 18.3%) concerning the ADG between the two experimental groups receiving 2.5 and 5% of bentonite respectively relative to the control at the goats of the Angora breed. The FCR is all the more improved in the presence of clay with a drop of (-14.9%) and (-18%) in the two experimental groups respectively compared to the control. This seems to be explained by the improvement of the ingestibility and the digestibility of the animals under the effect of the clay. This has been consolidated by the results of Ouachem *et al.* (2012).

In sheep, the results of several studies (Stojković *et al.*, 2005 ; Stojković *et al.*, 2010 ; Norouzian *et al.*, 2010, Kahouli *et al.*, 2020) are harmonized. These authors report that the growth performance (ADG, FCR, final weight) of lambs added by the clay either in the total ration or suspended in colostrum were significantly higher compared to those who received nothing.

It should be noted that the beneficial effects of clay on the growth of animals are attributed firstly to improving the health of newborns receiving the clay in colostrum or suspended in milk, or even of those descendants of the mothers who received clay peripartum which allows on the one hand a better food availability necessary for the fetal development in the last month of gestation, and on the other hand a better milk production in quantity like in quality (Ouachem and Soltane, 2009 ; Norouzian *et al.,* 2010 ; Zarcula *et al.,* 2010 ; Ouachem *et al.,* 2012); secondly, the optimization of digestive use including nitrogen use by reducing the share of ammoniacal nitrogen allowing microorganisms to intensify their proteosynthesis (Mohsen and Tawfik, 2002 ; Ouachem *et al.,* 2005 ; Koknaroglu *et al.,* 2006 ; Ural and Ural, 2017); and finally, the ability of the clay to capture various substances that can enter the body through food, thus preventing their bad effects such as mycotoxins, heavy metals, radionuclides and so on (Stojković *et al.,* 2005 and Stojković *et al.,* 2012).

Nevertheless, other results stand in the way of what has been reported before (Walz *et al.,* 1998 ; Tabbaa, 1999 ; Stojšić *et al.,* 2004 ; Ibrahim, 2012) find no noticeable effect of the clay on the growth parameters of lambs, ewes or rams, or even negative effects were recorded include the work of Toprak *et al.* (2016) and those of Estrada-Angulo *et al.* (2017) who found that the use of clay can have a detrimental impact on the growth performance of animals and carcass traits, as it can lead to decreased energy density and ingestibility ration explain them.

2. Effects on production performances

Dairy production is 25% dependent on the genetics of the animal, while it depends 75% on the environmental factors where diet is the dominate one (Ilić *et al.,* 2005 ; Ilić *et al.,* 2011). In other words, according to Đoković *et al.* (2011), the milk yield and the chemical composition of the milk depend on the breed, the food, the hygiene, the stage of lactation and even housing.

In this repect, Duval (1993) reports that the addition of bentonite to the dairy cow diet may or may not affect milk production and chemical composition. The nature of the ration, that is the proportion of fodder and concentrates, is the most important factor here, but the timing of adding bentonite to the diet may also be important. In his bibliographic review, he explains that :

- The addition of 5% bentonite to a ration of concentrates and hay in a ratio of 3: 1 increased the percentage of fat in milk by more than 50% ;
- There were no differences in milk composition between the addition of 5% or 10% bentonite in the diet. Milk production, however, was higher with the addition of 5% compared to control and the addition of 10%.

As well, this finding is further consolidated by more recent results. Ilić *et al*. (2011) found that the use of zeolite in the diet of dairy cows in the order of (2 and 4%) improves the quantity and quality of milk. The best figures were recorded in the group of cows receiving (2%) clay a significant difference of (+8%) and (+11%) of the quantity and the content of MG respectively in comparison with the control this was supported by the results of (Ilić *et al.,* 2005 ; Katsoulos *et al.,* 2006 ; Ilić *et al.,* 2011 ; Đoković *et al.,* 2011). Also, Ural (2014) come to reveal that the use of clinoptilolite in the total ration of dairy cows of the Holstein breed makes it possible to significantly increase the quantity of milk produced with a difference of more than 3L compared to witness. He adds that the clay also makes it possible to reduce the part of the somatic cells in the milk which improves its quality with a reduction of close to (-5%) of these in comparison with the control which in turn supports the result of (Parmigiani *et al.,* 2013 ; Micic *et al.,* 2017 ; Uyarlar *et al.,* 2018). And lately, Khachlouf *et al.* (2019) supports them, using zeolite (200g/d) in Holstein dairy cows found that PL increases by more than 2L/day compared to that which did not receive it, however that the chemical composition has not been affected. Katsoulos *et al.* (2006) and Khachlouf *et al.* (2019) add that this increase can be attributed to the increase of the production of propionic acid, the improvement on the one hand of the digestive use, and on the other hand to the proteosynthesis hence the increase in protein flow (see section : Effect on nutritional dynamics). Besides, Kahouli *et al.* (2020) report a similar results of kaolinite effect on ewes milk production, they assumed that ewes supplemented with 25g/head/day of kaolinite are significantly ($p<0.05$) highly milk-producing (+29%) during the first two months of suckling comparatively to the control ones.

In contrast, other results indicate that the use of clay does not appear to affect the quantity or quality of milk significantly in dairy cows according to the work of (Thilsing-Hansen *et al.,* 2002 ; Migliorati *et al.,* 2007 ; Agus *et al.,* 2014 ; Sulzberger 2016), although they indicate that sometimes an appreciable numerical improvement in the quantity and the quality of milk in the presence of different types of clays.

In addition, clay also appears to have an effect on the microbiological quality of milk. Several studies show its detoxifying effect by reducing the mycotoxins excreted in milk following the ingestion of contaminated feeds with fungi that can transmit contamination to milk through their metabolites such as Aflatoxin M1 (AFM1) (see section : Effect on health and animal welfare). Moreover, Sulzberger (2016) finds that clay significantly reduces the rate of mycotoxins (AFM1) in milk, a drop of its concentration of (-25%), (-18%), (-41%) in groups of cows receiving 0.5, 1 and 2% clay respectively. This is, according to the author, explainable by the high affinity of the clay for these metabolites in the digestive tract, which allows their sequestration in avoiding their digestion and intestinal absorption and therefore their transfer of rumen to the breasts. This revelation has also been supported by others, according to the results of the work that was carried out afterwards (Katsoulos *et al.,* 2012 ; Parmigiani *et al.,* 2013 ; Agus *et al.,* 2014 ; Micic *et al.,* 2017).

With regard to the production and growth of wool, the scientific results confirm the positive effect of clay on this performance. Previously, Fenn and Leng (1989) attempted to incorporate two types of sulfuric amino acids (cysteine and methionine) in the solid state or suspended in drinking water to quantify their effects on wool growth comparison with the effect of bentonite powder (30g/day) and in suspension (60g/day). Wool growth was higher in batches receiving bentonite added as a powder or in suspension, a difference of 19% and 20%, respectively, compared to the control group and better than the lots receiving the amino acids. This was well supported by the findings of (Fenn and Leng, 1991 ; Ivan *et al.,* 1992 ; Walz *et al.,* 1998) which report a similar trend of wool growth in the presence of bentonite, whereas, Eady *et al.* (1990) and Murray *et al.* (1990) contradict it. Indeed, the authors say that in the presence of clay, the digestibility improves, the proteosynthesis is accentuated, and because of this, the flow of proteins towards the intestine rises by supplying the growth of the wool in being sensitive of origin.

3. Effects on reproduction performances

Having been recognized for a long time by the scientific community, in most animals, the reproduction of figure among the performances most affected by food (Cloete, 1972 ; Stern *et al.*, 1978 ; Linsday *et al.*, 1993 ; Rekik *et al.*, 2005). In this regard, studies regarding the effect of clay incorporation on reproductive performance can be counted on the fingers. Generally, clay has no direct effects on reproductive function or even the reproductive organs, but indirectly through the promotion of digestibility (see section : Effects on nutritional dynamics) of animals which has a direct impact on body reserves and thus the BCS, thus on the restoration of the nutritional equilibrium of the animal by avoiding him the excesses and the protein deficiencies (see sections : Effects on nutritional dynamics and Effects on the ruminal ecosystem) which can affect on the reproductive function. It can also intervene by detoxifying the animal organism of certain toxic metabolites (see sections Effects on production performances and Effects on health and animal welfare) and which can be harmful on the physiological ways and the reproductive organs according to (Brugère-picoux, 2004 ; Pešev *et al.*, 2005 ; Blowey and Weaver, 2006 ; Mapham and Vorster, 2013) or by attenuating the effect of oxidative stress in the animal organism (Ipek *et al.*, 2012; Wu *et al.*, 2015) which can cause serious losses of reproductive capacity in males than in females (Natalija and Biljana, 2007).

The results of Karatzia *et al.* (2013) by adding (200g/day) of clinoptilolite reveal a significant decrease of all intervals reflecting a reproductive function, differences of (-6 days) for the calving-first heat interval, (-4) days for the calving interval-1st fertilization insemination, (-14 days) for the calving-conception interval and (-12 days) for the interval between two calvings in comparison with the control group of insemination performed to have a gestation is better in the experimental group, knowing that (72%) of cows in this group needed a single insemination to have a pregnancy while (28%) needed On the other hand, in the control group, (45%) cows were pregnant after the first insemination, (52%) after two inseminations, and (3%) after 3 inseminations, confirming the finding of Pešev *et al.* (2005) in fact, the amé The improvement in reproduction parameters according to the author is due mainly to the improvement in energy status and body condition of cows after ingesting clay. Knowing that these cows gained more BCS points (+0.57 points) compared to those in the control group. This has been reinforced by the work of Garzón Prado *et al.* (2017) which report that the use of 2% zeolite in the total peri-partum diet of Holstein dairy cows improves their fertility, significantly reducing the voluntary waiting period following the early return of ovarian activity and thus the early lifting of uterine involution compared to cows that did not receive clay. This is explained by the improvement of the immunity of cows by presenting less coincidences of uterine diseases, thus a better kinetics of body reserves in the peripartum. Recently, Pešev *et al.* (2018) also support the findings of the beneficial effect of the incorporation of clay in the diet of dairy cows on their reproductive performance.

Clay and environment management

The protection of the environment is a current area of concern. However, the development of livestock in the world is currently the subject of debate. Several scientific works and international reports point to its role in environmental imbalances

(Claude, 2002 ; Reyaud *et al.*, 2014). Methane is the major product of anaerobic fermentations of plant biomass occurring in the rumen (Chouinard, 2000 ; McDonald *et al.*, 2002 ; Jouany and Thivend, 2008). This metabolic pathway is an indispensable means for the elimination of the hydrogen produced during these fermentations (Jouany and Thivend 2008). Apart from (Sauvant, 1992 ; Demeyer and Fievez, 2000 ; Doreau *et al.*, 2011 ; Jouany and Thivend, 2008), methane is considered as the second greenhouse gas contributing to global warming after carbon dioxide (CO_2). According to Demeyer and Fievez (2000) and McDonald *et al.* (2002). Globally, the emission of CH_4 contributes about 16% in the greenhouse effect, 30% of this emission is natural, while 70% is anthropogenic, although that the emission of enteric gas (from animal digestion) is estimated at more than 20% of anthropogenic emissions. Otherwise, ammonia is also a product of ruminal fermentations, an intense ammoniogenesis causes the accumulation of ammonia which will be adjusted by the absorption at the ruminal level and the transformation into urea via the liver, a part of the latter will be recycled in the form of salivary urea, and the excess will be eliminated by the kidneys via the urinary tract (Jarrig, 1988 ; Meisinger *et al.*, 2001 ; Wattiaux, 2004). This is another challenge for the environment and public health, as nitrogenous waste contributes on the one hand to the pollution of groundwater and surface water by nitrates, and on the other hand, emanations of ammonia likely to release protons contributing to the acidification of the rains according to (Barret, 1992 ; McDonald *et al.*, 2002 ; Wattiaux, 2004).

As for clay, it has proven itself in ecological animal production. As aroused (see see clay-parameter section of rumen), On the one hand, clay can reduce methanogenesis in the rumen. This is supported by several scientific results indicating the fall of the part of the CH_4 produced following the ruminal fermentations in the presence of the different types of clays, Tate *et al.* (2015) reveals via an *in-vitro* study that the use of kaolinite has allowed a significantly significant reduction of approximately (65%) compared to a control batch after 7h of incubation. Similarly, Laibi *et al.* (2015) indicates that the use of complex clay (smectite, kaolinite, quartz) remarkably reduces methanogenesis in sheep. This is consistent with the previous findings reported in the study of Abdl-Rahman (2010) and Kardaya *et al.* (2012) conducted in the same context using fumaric acid-bound bentonite and urea-impregnated zeolite respectively, and with recent results of Dal Pozzo *et al.* (2016) and Sulzberger *et al*. (2016) using montmorillonite and a mixed clay respectively.

Doreau *et al.* (2011) says that the net production of hydrogen can be reduced following a partial or total suppression of the population of protozoa (defaunation) in the rumen, besides, elicited (section : Effects on the ruminal ecosystem), the clay affects the protozoan population by reducing its density (Abdullah *et al., et al.*, 1995 ; Filya *et al.*, 1999 ; Forouzani *et al.*, 2004 ; Khalifeh *et al.*, 2012) which explains part of the reduction of methanogenesis. However, the increase in the production of propionic acid under the effect of clay (see section : Effects on the ruminal ecosystem), can explain the other part of the decrease of the methanogenesis due to the inverse relation between the methanogenesis and the production of propionic acid which is characterized by intense biohydrogenation by depleting the primary substrate for the production of CH_4 (Chouinard, 2000).

On the other hand, the clay reduces the ammoniogenesis in the rumen, and therefore the ureogenesis, and consequently the nitrogenous effluents. Moreover, the efficiency of lowering ammoniogenesis in the rumen by means of clay (Wallace and Newbold, 1991 ; Ouachem and Nouicer, 2006 ; Ghaemnia *et al.*, 2010 ; Goodarzi and Nanekarani, 2012) has been deeply discussed before (see section : Effects on the ruminal ecosystem), this is in addition to what we have already pointed out about the effect of clay on the serum urea level, where it has been proven to reduce the plasma urea level (Katsoulos *et al.,* 2006 ; Ghaemnia *et al.,* 2010) in consequence of a fall of the ammoniagenesis (see section : Effects on biochemical profil), namely, nitrogen droppings will be minimized s under the effect of the clay.

Conclusion

- Clay, an abundant and inexpensive natural biological product, has proven its usefulness in handling ruminal fermentations and improving animal performance and overall health.
- Use of clay is advantageous in intensive systems using a diet rich in concentrate because of its buffering capacity, stabilizing ruminal fermentations, modifying the structure and metabolism of rumen microbiota in favor of better digestive use and therefore good externalization of the performances in the respect of the current requirements of the consumers and the ecological standards recommended.
- Clay must take the magnitude that deserves as alternative of therapeutic chemical substances and antibiotics for more biological, ecological and healthy livestock production.

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