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Effect of incorporation of carob (*Ceratonia siliqua* L.) in the diet of fattening rabbits.

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“For my daughter Elena, My wife and my family,

The only reason

Statistically significant of all things.”

“P value always <0.05”

"It is not the mountain we conquer, But ourselves”

Edmund Hillary,

Monte Everest 1953, with Tenzing Norgay.

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GUENAOUI MOHAMED

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Abstract:

The aim of this work was to study the utilization of carob pods by rabbits and its effect on growth performance, health status and economic efficiency in fattening period. The analysis shows that our carob has a low content in CP (4,2%) but a high content in fiber (20,7%).For growth performances the use of carob separated or incorporated in rabbits diets improve feed intake of animals because of its high palatability without any effect on growth rate. However, carob has a positive effect on health status of animals by decreasing the problems of diarrhea after weaning. For digestibility carob improve the apparent digestibility of dry matter and organic matter but has a negative effect on proteins and fat digestibility.

Therefore, Local raw materials as carob deserve to be studied more precisely, which could be considered as an alternative source in rabbit nutrition comparable to other more common ingredients such as barley and corn.

Key words: Rabbits, carob, digestibility, growth, Mortality, food.

Resumé:

Le but de ce travail était d'étudier l'utilisation de la caroube par les lapins et son effet sur les performances de croissance, l'état de santé et l'efficacité économique en période d'engraissement. L'analyse montre que notre caroube a un taux faible en PB (4,2%) mais riche en fibres (20,7%). Pour les performances de croissance, l'utilisation de la caroube séparée ou incorporée dans l'alimentation des lapins améliore la consommation alimentaire des animaux à cause de sa haute palatabilité sans aucun effet sur le taux de croissance. Cependant, la caroube a un effet positif sur l'état de santé des animaux en diminuant les problèmes de diarrhée après le sevrage. Pour la digestibilité, la caroube améliore la digestibilité apparente de la matière sèche et de la matière organique mais a un effet négatif sur la digestibilité des protéines et de la matière graisse.

Par conséquent, les matières premières locales comme la caroube méritent d'être étudiées plus précisément, ce qui pourrait être considéré comme une source alternative dans la nutrition du lapin comparable à d'autres ingrédients plus courants tels que l’orge et le maïs.

Mots clés: Lapins, caroube, digestibilité, croissance, Mortalité, alimentation.

الملخص :

كان الهدف من هذا العمل هو دراسة استخدام الخروب بواسطة الأرانب وتأثيره على أداء النمو والصحة والكفاءة الاقتصادية أثناء التسمين. يظهر التحليل أن الخروب لديه معدل منخفض من البروتينات (4.2 ٪) ولكنه غني بالألياف (20.7 ٪). بالنسبة لأداء النمو، فإن استخدام الخروب المنفصل أو المدمج في تغذية الأرانب يحسن من استهلاك العلف للحيوانات بسبب لذته العالية دون أي تأثير على معدل النمو. ومع ذلك، فإن الخروب له تأثير إيجابي على صحة الحيوانات من خلال الحد من مشاكل الإسهال بعد الفطام. من أجل الهضم ، يحسن الخروب من الهضم الظاهر للمادة الجافة والمواد العضوية ولكن له تأثير سلبي على هضم البروتينات والدهون.

لذلك، فإن المواد الخام المحلية مثل الخروب تستحق مزيدًا من الدراسة، والتي يمكن اعتبارها مصدرًا بديلًا في تغذية الأرانب مقارنة بالمكونات الأخرى الأكثر شيوعًا مثل الشعير والذرة.

الكلمات المفتاحية: الأرانب ، الخروب ، الهضم ، النمو ، الوفيات ، التغذية.

ABREVIATIONS KEYS

a: Allometry

AA: Amino Acids

DE: Digestible Energy

CP: Crude Protien

DM: Dry Matter

DP: Digestible Protiens

DWG: Daily Weight Gaine

EAA: Essential Amino Acids

ERE: Epizootic Rabbit Enteropathy

FA: Fatty Acids

GLM: General Linear Model

H : Hour

LW: Live Weight

M mol: Milli mole

MUFA: Mono Unsaturated Fatty Acids

NSP: Non Starch Polysaccharides

PB: Protéines brutes

PUFA: Poly Unsaturated Fatty Acids

SFA: Saturated Fatty Acids

V: Voltes

VFA: Volatile Fatty Acid

W: Weight

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Introduction

Developing countries have a large deficit in animal protein. The rabbit is recommended as an adequate alternative to remedy this deficiency. Indeed, rabbits can represent a significant source of protein in Algeria, because of their prolific nature and their ability to use agro-industrial by-products (Gacem and Bolet, 2005). Currently in Algeria several farms are being set up, industrial food production units are being created and rabbit meat is increasingly offered in the markets. But before that, several attempts to promote this production since the 1980s have failed due to deficiencies in the factors of production, notably the absence of quality of industrial food with an affordable price (Berchiche and Lebas, 1990; Kadi et *al.*, 2012).However, farmers have many difficulties which slow down the development of this kind of production, in particular because of the unavailability of peleted feed respecting the nutritional needs of the rabbit in fattening period.

Several works have been carried out with the aim of incorporating local raw materials and by-products (faba bean, Sulla, olive pomace, pomace grape…) into the rabbit's diet for reproduction and growth in rational production in Algeria (Berchiche, 2009).

In arid and semi-arid areas, the availability of carob (*Ceratonia siliqua* L.) is very important. The uses of *Ceratonia siliqua* are numerous and its value as forrage can contribute to the improvement of the pastoral potential of the country. All the components of the tree (foliage, flower, fruit, wood, bark, and root) are beneficial, it is considered to be one of the fruit and forest trees which represent the greatest potential for development thanks to its richness in nutritive elements which has attracted the attention of several researchers.

In Algeria, among the major problems encountered in the rabbit breeding sector is the price and the quality of food. For quality, the commercial pelleted food available is often characterized by its low fiber content and its use leads to significant loss of animals through diarrhea (up to 50%). For price, the food cost corresponding to 60% of the production cost, the high price of the food remains one of the major obstacles to the development of this sector. In large part, the raw materials used in food fabrication are imported and excessively expensive; this is the case with alfalfa, soybean meal, corn, etc… Faced with these problems, breeders resort to specific feeding practices such as supplementing the pelleted food with a distribution of straw or other fiber sources raw materials to enhance health status of animals. In the other hand, the research of cheap raw materials is indisponsible to reduce the cost of food. Several researches show that the use of carob has a benific effect in animal nutrition because of its high contenent in gross energy and fiber. However, carob is largely used in animal feed against diarrhea for its high level in tannins (Würsch, 1987) and used to treat diarrhea in babies (Loeb et *al*., 1989). In addition, the carob is cheaper in Algeria (12 to 15 DA/Kg) and may reduce the price of 1kg of pelleted food.

Therefore, the main objective of this work is the research to valorise one of the most available raw materials in Algeria, which is carob and to see the effect of its use in rabbit's nutrition.

The bibliographic study shows that the post-weaning period in different animals is the most critical in their life and to fight against this problem several strategies were used, particularly feeding. This fact has been studied in particular in piglets and rabbits, where it has been found that food plays a very important role in this period. Finding the ingredients and products added to the food can solve the problem without affecting production performances. However, in rabbits, where the digestion problem after weaning is particularly significant, there is practically no information in this regard.

The general objective of this work is to test the effect of the use of a natural product in the feeding of rabbits after weaning and in the fattening period, which is carob. For this, three experiments were made to arrive at the objectives of this work:

- See the acceptability of carob by young rabbits at weaning;

- The effect of carob on growth performances in fattening rabbit;

- The effect of carob on animal health;

- The effect of carob on digestibility in rabbits;

- The effect of carob on carcass yeild and digestive performances;

- The economic efficiency of incorporating carob into rabbit feed formulas.

LITERATURE REVIEW

1- Growth performances in growing rabbits :

1-1- Definition of growth:

Growth is the set of changes in weight, anatomical and biochemical composition of animal's body from conception to adult age. It is the result of a set of complex mechanisms involving cell multiplication and differentiation of tissues. It is controled by precise physiological laws but can vary under the effect of genetic (breeds) and non-genetic factors (food), maternal effect and general environment. Growth represents the difference between what is constructed or anabolism and what is destroyed or catabolism (Bertalanffy, 1960, Prud'hon et *al*., 1970, Ouhayoun, 1983).

1-2- Growth between birth and weaning:

This period varies between 4 and 6 weeks. The growth of rabbits before weaning is conditioned by the milk production of the does (lebas, 2000). Between the 2nd and 3rd weeks after birth, the growth of rabbits is slowed down (Lebas, 1969). Rouvier (1980), report that the growth rate between 10 and 21 days can decrease because of the milk deficiency of the rabbit. According to (Ouhayoun, 1978), the growth of young rabbits depends strongly on the maternal environment: the size of the litter and the capacity of the rabbit to cover the needs of its young rabbits in quantity and quality.

1-3- Post-weaning growth:

It is frome weaning until the end of fattening, the growth of rabbits depends on the food distributed; its maximum is obtained around the 7th and 8th week (Ouhayoun, 1990) and (Blasco and Gomez, 1993). According to (Blasco, 1992), the period of fattening varies by country. In Europe, it ends at age 10 to 11 weeks with a weight of 2.3 kg, which corresponds to the maturity rate of 55% of an adult weight of 4 kg (rabbit at the age of 2 years). Growth performance varies by population; the selected strains are more efficient than the local populations .According to Berchiche et *al.* (1998), the local rabbit fed with balanced pellet is able to reach live of 1900g at 13 weeks of age.

1-4- Growth rate :

The average daily weight gain (DWG = W2 - W1 / a 2 – a 1) expresses the growth rate (Figure 1). Between birth and weaning, the growth rate is very high. During this period, the weight of the rabbit is multiplied by 10 (Ouhayoun, 1983). However, the daily growth curve shows a pause between the 2nd and 3rd weeks, which would be due to insufficient maternal milk production (Lebas, 1969). The overall growth curve of the rabbit is a sigmoidal curve, with an inflection point between the 5th and 7th week of postnatal life (Prud'hon et *al*., 1970) when weaning is performed at 4 weeks. Between 4 and 11 weeks of age, the growth curve can be considered linear (Ouhayoun, 1978). Then it decreases steadily until the age of 6 months (Cantier et *al*., 1969). Males and females follow a similar growth curve until sexual maturity at about 12-15 weeks of age (Harvey et *al*., 1961, Rollins et *al*., 1963 Cantier et *al*., 1969). After, females become heavier than males (Ouhayoun, 1983). Feed intake becomes important only at the age of three weeks, when the lactation of the rabbit begins its fall. At the age corresponding to the point of inflection of the growth curve in S, between the 5th and 7th postnatal week, the growth rate is maximal. Then it slows down gradually and tends to zero around the age of 6 months.

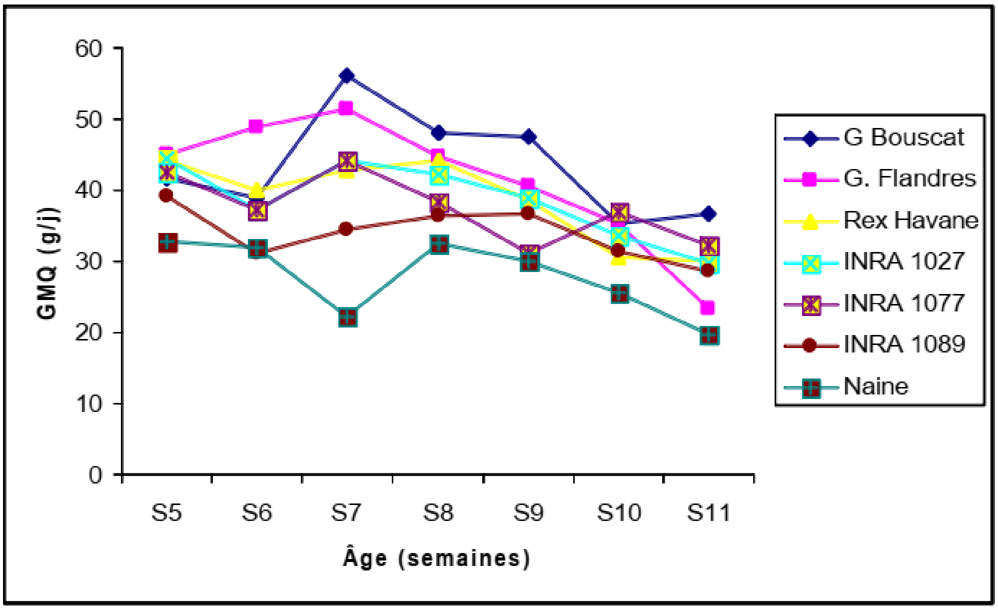

Figure 1: Growth parameters in rabbits (Ouhayoun, 1978).

1-5- Relative growth and allometric coefficient:

The overall growth rate of the body results from the particular growth of its various components. These do not develop all at the same rate: this is what defines allometry (Ouhayoun et *al*., 1986a). The composition of the carcass of a growing rabbit is the result of the relative development of the three main tissues: bone, muscle and fat. The balance of these tissues changes during growth (Ouhayoun et *al*., 1986a and b, Cantier et *al*., 1969). The proportion of bones decreases to 1 kg of body weight while the proportion of muscle tissue increases to around 2.5 kg; between these two weights, the muscle / bone ratio of the hind limb, which accounts for the relative development of the musculature and skeleton of the whole of carcass, therefore it grows very fast. More than 2.5 kg of weight, the muscle growth allometry is minor (a = 0.50) and the muscle / bone ratio then decreases. The fat tissue grows faster than the body (a = 1.87) between body weights of 1 and 2.2 kg. More than this weight, the relative growth of fat tissue is even faster (a = 3.21).The skin, like fat tissue, has an increase in the allometric coefficient during the development of the animal.

The digestive tract, developed very early probably because of the special feeding of young rabbits that fed only once a day by their mother (Prud'hon et *al*., 1970). The liver, after a major allometry phase (a = 1.25 for males, 1.27 for females), has a slower growth than the body. The kidneys first show an isometric growth phase followed by a minor phase.

The growth allometry of the carcass compared to the whole body is slightly greater (a = 1.09) (Ouhayoun, 1980). This result is in agreement with those of Cantier et *al* (1969), where it was found that during growth, the blood, the digestive tract and the skin present a minor growth allometry.

1-6- Factors Influencing Growth:

Several factors can influence the growth and body composition of rabbits, the most important of which are breed, food and environmental factors.

1-6-1- Genetic factors:

The rabbit is distinguished from other species by a very large variability of weights between breeds, strains and crosses (Ouhayoun, 1978). Ristic (1986) attributes to the genetic type the strongest influence on growth and meat characteristics. Thus, slow-growing animals have a lower-fat carcass than fast-growing ones (Ouhayoun, 1983).

1-6-2- Feeding factors:

Protein levels influence significantly the rate of growth that accelerates with high protein levels (Lebas and Ouhayoun, 1987). A supply of essential amino acids is important. According to Berchiche (1985), a deficiency of methionine causes an alteration of the growth rate. Lebas et *al*. (1982) found that the energy concentration of foods does not alter growth rate. Moreover, Greppi et *al*. (1988) found that an increase in the protein content of the food does not improve the weight gain when the amount of energy consumed is restricted. According to Parigi Bini (1988), the optimum ratio ensuring a maximum daily weight gain is between 43 and 45g of digestible protein / Kcal of digestible energy.

1-6-3- Environmental factors

The effect of the season on the growth of young rabbits depends greatly on rearing conditions, post-weaning growth rate is better during the winter months, early spring and autumn (Ouhayoun, 1983). Lebas and Ouhayoun (1987), note a reduction in the growth rate when the temperature is high. According to Baselga, (1978), the temperature acts on the modification of the appetite of the animals, the summer temperatures, in particular reduce the food intake.

2- Digestion in rabbit :

The digestive system of the rabbit is characterized by the relative importance of the caecum and colon when compared with other species (Portsmouth, 1977). The caecum has a great importance for the processes of digestion and nutrient utilization, but also in the control of digestive pathologies. Furthermore, the rabbit is characterized by the behaviour of the ingestion of soft feces, makes microbial digestion in the caecum more important for the overall utilization of nutrients by the rabbit, which is named caecotrophy.

2-1- Digestive System of the Rabbit :

The rabbit is an herbivore, but because of its small size and high metabolic rate, it has developed a different digestive tract than other herbivores, such as horses or ruminants. Herbivores have large digestive pools that allow efficient use of fiber diets. The digestive tract of the rabbit is composed of a succession of compartments whose mucous membrane is in contact with food: the mouth, esophagus, small intestine, cecum, colon, and then rectum abutting the anus (Figure 02).

The first important compartment of the digestive system of the rabbit is the stomach; this has a very weak muscular layer and is always partially filled. The capacity of the stomach is about 0.34 of the total capacity of the digestive system (Portsmouth, 1977). The stomach is the site of digestion of caecotrophes. Thus, the stomach is continuously secreting and the pH is acid. The stomach pH ranges changes from 1 to 5, depending on site of determination (fundus versus cardiacpyloric region) (Gutiérrez et *al*., 2002, 2003; Chamorro et *al*., 2007; Orengo and Gidenne, 2007; Gómez-Conde et *al*., 2009), the presence or absence of soft feces (Griffiths and Davies, 1963), the time from feed intake (Alexander and Chowdhury, 1958) and the age of the rabbit (Grobner, 1982). The stomach is linked with caecum by a small intestine approximately 3 m long, where the secretion of bile, digestive enzymes and buffers occurs.

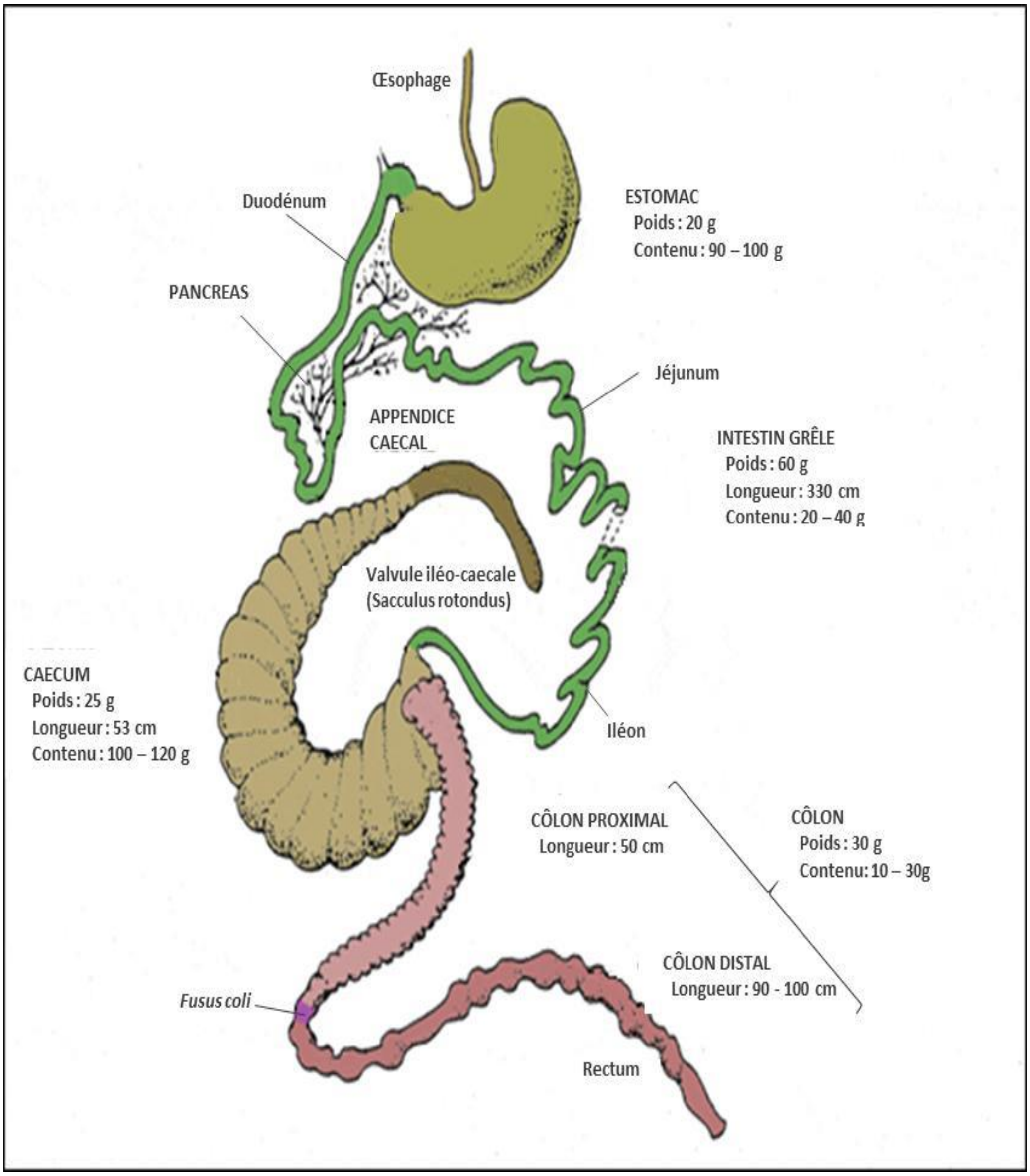

Figure 02: Digestive systeme of the rabbit (Lebas, 1998)

2-1-1- Small intestine:

The small intestine can be divided into three sections: the duodenum, the jejunum, and the ileum (Figure 02). The jejunum is the longest part of the small intestine. The ileum terminates by the ileocecal valve, or sacculus rotondus, which marks the junction between the ileum, the cecum and the colon. The ileocolic valve controls the movement of food ingested from the ileum to the cecum and prevents their reverse movement. The small intestine represents about 12% of the digestive tract in adult rabbits (Lebas et *al*., 1996). The small intestine is the main site for nutrient absorption. In order to increase its absorption capacity, the wall consists of connective valves, and macroscopic circular folds. The mucosa of the small intestine is covered by millions of small villis that extend about 1 mm into the lumen.

2-1-2- Caecum:

The caecum is characterized by a weak muscular layer and contents with a dry matter (DM) of 200 g kg^{-1}. The relative share of the cecum in the digestive tract is greater in rabbits than in all other mammals. It is twice the length of the abdominal cavity and can contain 40-60% of the digesta (Lebas et *al*., 1996, Davies and Davies, 2003). The cecum provides a favorable environment for anaerobic fermentation by the microbiota. The caecal mucosa does not formed by villi but presents crypts (Snipes, 1979). The luminal surface is lined by a cylindrical epithelium with a well-developed microvilli border (Snipes, 1979). Its wall is also made up of lymphoid tissues, and absorbent cells. The spiral folds and the muscular layer present in the cecal wall contribute to the progression of feces in the corpus of the cecum by peristaltic movements that allow the formation of soft feces and the practice of caecotrophy (Snipes, 1979). The retention time of food in the rabbit cecum is relatively long and varies between 7 and 42 h, depending on the size of the particles (Gidenne et *al*., 1985, Gidenne, 1997). This retention time would be on average from 7 to 16 hours for gross particles (> 300 µm), and from 16 to 42 hours for the finest particles (<300 µm) and liquids (Gidenne, 1997).

2-1-3- Colon:

The caecal content passes through the caecal bulb and enters the colon. The colon is divided into 2 sections, the proximal colon and the distal colon. The proximal colon is subdivided into three parts: the first part has three longitudinal folds, and contains evaginations, which represent a significant increase of the exchange surface and could help the separation of the solid and liquid phases for the formation of feces. The second segment having only one large haustration, and the last segment, the fusus coli, characterized by an absence of haustration, is slightly strengthened compared to previous segments. The second section, the distal colon, is the longest segment, up to 100 cm in length, and is often filled with fecal pellets. The wall of the distal colon then becomes smooth and educts on the rectum, then on the anus.

2-2- Digestive physiology :

2-2-1 Enzymatic digestion:

In rational farming, the food is distributed in the form of pellets with high dry matter content (about 90%). The enzymatic digestion of food begins in the mouth where mastication is the first step of digestion. The mastication reduces the size of the food particles and mixes the food bolus with different enzymes that ensure the begining of chemical degradation (Davies and Davies, 2003).After; the food bolus reaches the stomach, which is the main site of enzymatic digestion. The stomach produces gastric lequid with different types of secretions. These secretions are hydrochloric acid participating in the acidification of the medium. This level of acidity has a role in digestion, including protein denaturation and enzyme activation, but also preserves animal health through inactivation of ingested microorganisms, making the stomach and the small intestin almost sterile (Martinsen et *al.*, 2005). The stomach is the sit of the beginning of the digestion of lipids and proteins.

The digestion of proteins begins in the stomach under the action of pepsin secreted by the main or zymogenic cells in an inactive form called pepsinogen. It is activated by gastric acidity, allows the denaturation of proteins in peptides.

The digestion of fatty acids also takes place in the stomach, by the action of gastric lipase (Moreau et *al*., 1988). This lipase preferentially hydrolyzes short or medium chain of fatty acids by an optimum pH between 5 and 6 (Perret, 1982; DeNigris et *al*., 1988; Moreau et *al*., 1988; Rogalska et *al*., 1990).

After 2 to 4 hours in the stomach, the bolus is sufficiently stirred with the gastric secretions. Then, the chyme is evacuated to the duodenum.

2-2-2- Cecal or microbial digestion:

The second type of digestion in mammals is microbial digestion. This digestion is an important part of the process of food degradation in herbivores. The microorganisms that colonize the digestive tract allow the degradation of food particles that have not been digested by enzymatic digestion of the animal, especially fibers, and endogenous molecules, mainly protein (Forsythe and Parker, 1985).In rabbits; the digestion of parietal carbohydrates takes place mainly in the cecum and requires the intervention of bacterial enzymes. Dietary fiber is the main source of carbohydrate for caecal bacteria. These are lignin (non-carbohydrate) and non-starch polysaccharides (NSP) which are degraded to hexose and pentose by bacterial enzymes. Then, they are fermented in pyruvates and this latter are transformed into volatile fatty acids (VFA) with gas production (H_2, CO_2 and CH_4). The VFA produced as a result of fermentation are short-chained acids used by the rabbit as a source of energy covering 10 to 40 % of maintenance needs.

2-2-2-1- Colonization of the microbiota:

The process of colonization of the digestive microbiota of rabbits is similar to that of humans and most animals (Mackie et *al*., 1999). From birth, the animal is contaminated with a heterogeneous collection of microorganisms from the birth canal and the immediate environment (Berg, 1996, Combes et *al*., 2011). At the time of setting up the ingestion of solid food and the caecotrophs, the composition of the stomach microbiota seems constant. The bacterial concentration increases with age and can reach 104 to 106 / g in the stomach at 30 days of age (Fortun-Lamothe and Gidenne, 2003a). In the intestine, the presence of microflora has been observed from the first week of life (Carabaño et *al*., 2006). The microbial concentration in the intestine is 10 to 100 times higher than in the stomach (106 to 108 / g) for rabbits of 7 days old (Fortun-Lamothe and Gidenne, 2003a). In the colon and cecum, concentrations range from 107 to 109 / g after the first week of age (Fortun-Lamothe and Gidenne, 2003a) and increase to 10^{10} bacteria / g of content in the second week of life (Carabaño et *al*., 2006).

2-2-2-2- Characterization of the caecal ecosystem:

The caecal ecosystem can be defined as the association formed by the microorganism community (biocenosis) and the caecal environment (biotope) (Gidenne et *al*., 2007a). Caecal biocenosis is constituted of many microorganisms that play an important role in digestion. The caecal microbiota is essentially composed of strict anaerobic bacteria and facultative anaerobic bacteria. The strict anaerobic bacterial population is characterized by a clear predominance of the strict non-sporulating anaerobic bacteria (10^{10} to 10^{11} bacteria / g) of the kind *Bacteroides* (Gouet and Fonty, 1979). The facultative anaerobic microbiota appears in the first week of age and consists exclusively of enterobacteria such as *Escherichia coli* and *streptococci*.

2-2-2-3- Fermentative activities of the caecum:

The amylolytic and cellulolytic activity results in the production of simple carbohydrates, which are fermented by other bacteria to produce VFA. The major VFAs are acetate, propionate and butyrate. The caecal concentration of total VFAs increases with the age of the rabbit, between 15 and 22 days, the concentration increases from 8 to 34 m mol / l of the caecal content and more than 50 m mol / l at weaning (28 days). It reaches 70 m mol / l at 45 days (Figure 03) (Padilha et *al*., 1995, Gidenne et *al*., 2007a).

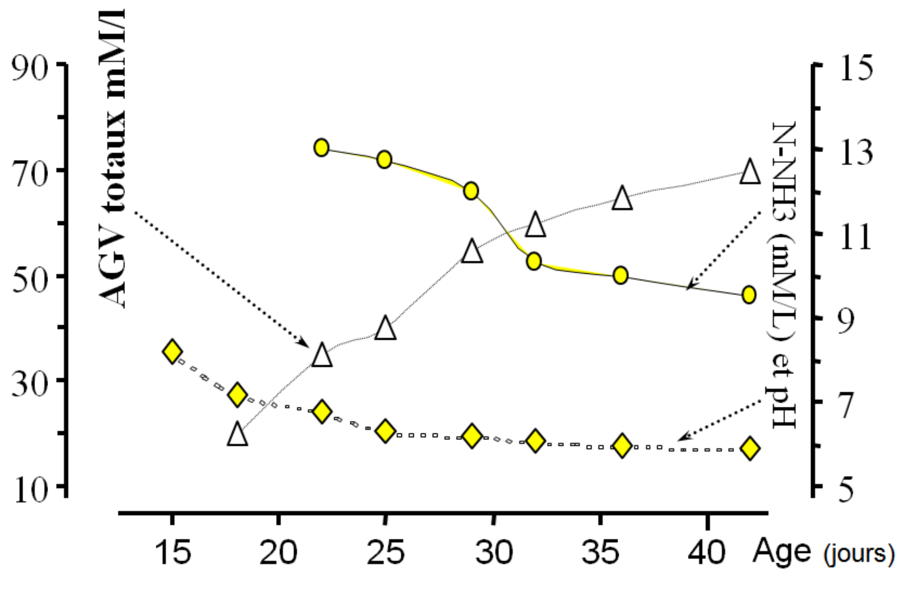

Figure 03: Evolution of caecal fermentative activity with age (Fortun-Lamothe and Gidenne, 2001)

2-2-2-4- Effect of diet on the evolution of the bacterial community in the ceacum:

The ingestion of solid food influences the development of microbial flora in the digestive tract.In addition; exclusive ingestion of milk appears to delay colonization by cellulolytic bacteria without affecting the E. coli population (Padilha et *al*., 1995; Padilha et *al*., 1999). Moreover, if the establishment of coprophagy behavior, which is consecutive to the introduction of the ingestion of solid food, is inhibited, then the ecological succession in the bacterial community is delayed, with a relative abundance of *Bacteroidaceae* and *Ruminococcaceae*, respectively (Combes et *al*., 2014).

2-3- Digestion and intestinal absorption :

The intestinal digestion is done with the help of other glands that are the liver and pancreas. Acid chyme from the stomach is neutralized by active pepsin from the liver, by bicarbonate contained in pancreatic secretions and mucosa, and Brunner's glands of the duodenal mucosa (Baron 2000, Konturek et *al*., 2004). The pancreas produces two types of secretions: endocrine and exocrine secretions. Exocrine secretions include trypsin, chymotrypsin and carboxypeptidases. Protein degradation, or proteolysis, is achieved by these pancreatic proteases to be completed by the enterocyte peptidases, mainly in the duodenum and jejunum (Davies and Davies, 2003). Peptides derived from the action of proteases are hydrolysed to amino acids by the peptidases of the brush border and the cytoplasm of the enterocytes. The amino acids obtained from digestion are absorbed in the intestine. The absorption of these later is done by diffusion if the structure of the amino acids has hydrophilic properties. Otherwise, the absorption is done via independent or dependent sodium ion transporters. Although, most of the ingested protein is hydrolyzed to amino acids in the intestine, some of it is able to enter the bloodstream as peptides (Erickson and Kim, 1990).

Digestion of lipids is preceded by their emulsification by bile salts secreted by the liver. The bile is secreted by the hepatocytes, then stored in the biliary visicle before passing through the biliary way and enters the proximal part of the duodenum just after the pylorus. Hydrolysis of lipids releases fatty acids, mono and di-glycerides, glycerol, phosphatidylcholine and cholesterol. They are absorbed by passive diffusion or by transporters through the intestinal membrane.

The digestion of carbohydrates (starch) is ensured by pancreatic amylase. It acts on the α-1-4 osidic bonds of amylose and amylopectin. This hydrolysis leads to the formation of maltotrioses, maltoses and dextrins in the intestinal suc (Corring and Rerat, 1988). Then, the oligo- or di-saccharidases (α or β) of the intestinal mucosa intervene at the end of digestion to release simple oses. The released oses are absorbed by the enterocyte brush border by passive transport (fructose) or active transport with sodium. The passage of these sugars (galactose and glucose) to the blood is carried out by passive transport at the level of the enterocyte membrane (Wright et *al.*, 2003).

2-4- Caecotrophy and hard feces :

The excretion of caecotrophs (in a cluster and covered with mucus) and hard feces are 2 distinct mechanisms that take place at different times of the day. The excretion rate of these 2 types of fecal pellets is dependent on the ingestion rate of rabbit. Hard feces are emitted in large quantities at night, where the ingestion of food is the most important.While the caecotrophs are emitted during the period of low ingestion in the morning and early afternoon in a global period of about 7 hours. Caecotrophy occurs through the dual-mode operation of the proximal colon. Caecotrophs are caecal contents that pass through the colon without significant changes (fine and gros particles). On the other hand, the production of hard feces, involves many modifications of the caecal contents during its last passage in the proximal colon. When the caecal content engages in the proximal colon, the latter presents a succession of contractions with alternating peristaltic contractions, then antiperistaltic contractions. Thus, the large particles (> 300 µm), mainly the fibers, continue their transit to the distal colon, the fine particles are sent back to the cecum for further bacterial degradation (Figure 04)

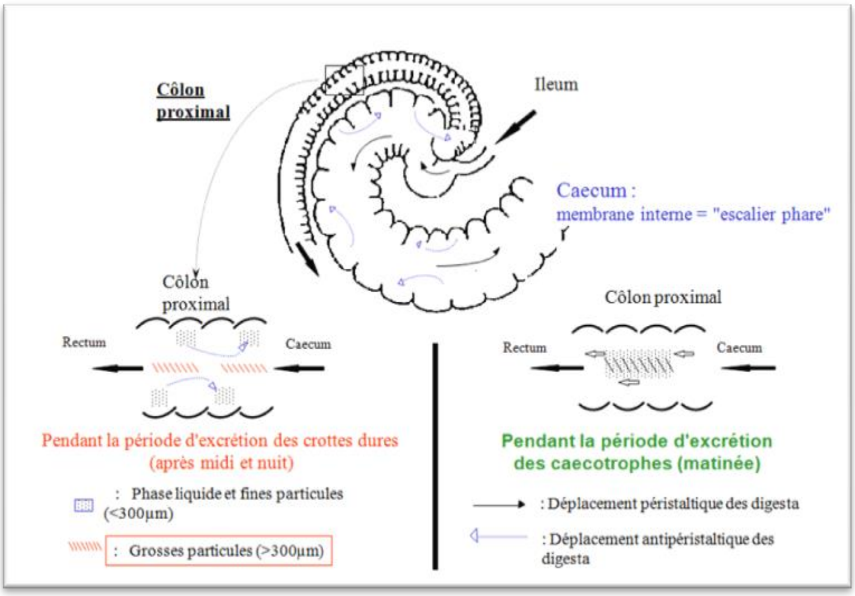

Figure 04: Movement of digesta in the caeco-colic segment (Gidenne, 1997)

The practice of caecotrophy has a great nutritional value because of its high biological value of protein (about 30% of microbial origin) and water-soluble vitamins (Gidenne and Lebas, 2006). The composition of the caecotrophs is similar to that of the caecal content but different from that of the hard feces (Table 1).

Table 01: Chemical composition of caecotrophs and hard feces in % of DM (Gidenne and Lebas, 2006)

	Hard feces	**Caecotrophs**
DM %	48-66	18-37
CP	9 -25	21-37
Crude fiber	22-54	14-33
Fat	1.3 - 5.3	1.0 - 4.6
Ash	3 -14	6 -18

3- Slaughter parameters and rabbit's meat:

3-1- Slaughter technology and yield:

Slaughter technology has been the subject of many researchs. However, some of the modalities of the first processing may have an impact on the meat value: the yield, the appearance of the carcasses or the hygienic and organoleptic quality of the meat. Under the practical conditions of production, the fasting of rabbits before their departure to the slaughterhouse has a little interest, since it modifies little of the contents of the digestive tract. However, it leads to a reduction of 2% in the yield at slaughter (when the fasting period is between 6 to 24 hours: Szendro and Kustos, 1994), from 5 to 6 % of the carcass weight and significantly modifies the characteristics of the carcasses meat.

According to Masoero et *al*. (1992) and Szendro and Kustos (1994), transport also affects the live weight of animals: the weight losses are greater when the transport is long; weight loss varies from 1.4 to 4.6 % when the transport time increases from 1 to 8 hours (Luzi et *al*., 1994, Trocino et *al*., 2003). On the other hand, no serious deterioration of meat quality due to transport conditions has been reported in rabbits (Ouhayoun and Lebas, 1994).

The rabbit is slaughtered by electrocoma (voltage less than 90 V and electroshock up to 350V). According to Vorob'ev and Stankovski (1979), decapitation allows rapid and complete bleeding; it facilitates skinning and provides a lighter meat. However, the section of jugular vein and carotid artery remains the most common method (Ouhayoun, 1990).

3-2- Characteristics of a carcass :

The optimum slaughter age for meat quality and its cost of production are determined by the age and adult weight of the animals (size and maturity). However, the optimum degree of maturity of the rabbit is 55-60%, slaughter yield (57%), muscle / bone ratio (6) and carcass fat (≥ 3%) are of a good level (Ouhayoun, 1990). The increase in slaughter yield by weight may justify the slaughter as late as possible, but taking into account fat rate (increase above 2.3 kg) and muscle / bone ratio (tendency to decrease at more than 2.7 kg), while the optimum slaughter weight is 2.5 kg (Ouhayoun, 1990). Figure shows the carcasse yeild of rabbits at a weight of 2.3 Kg (Ouhayoun, 1990).

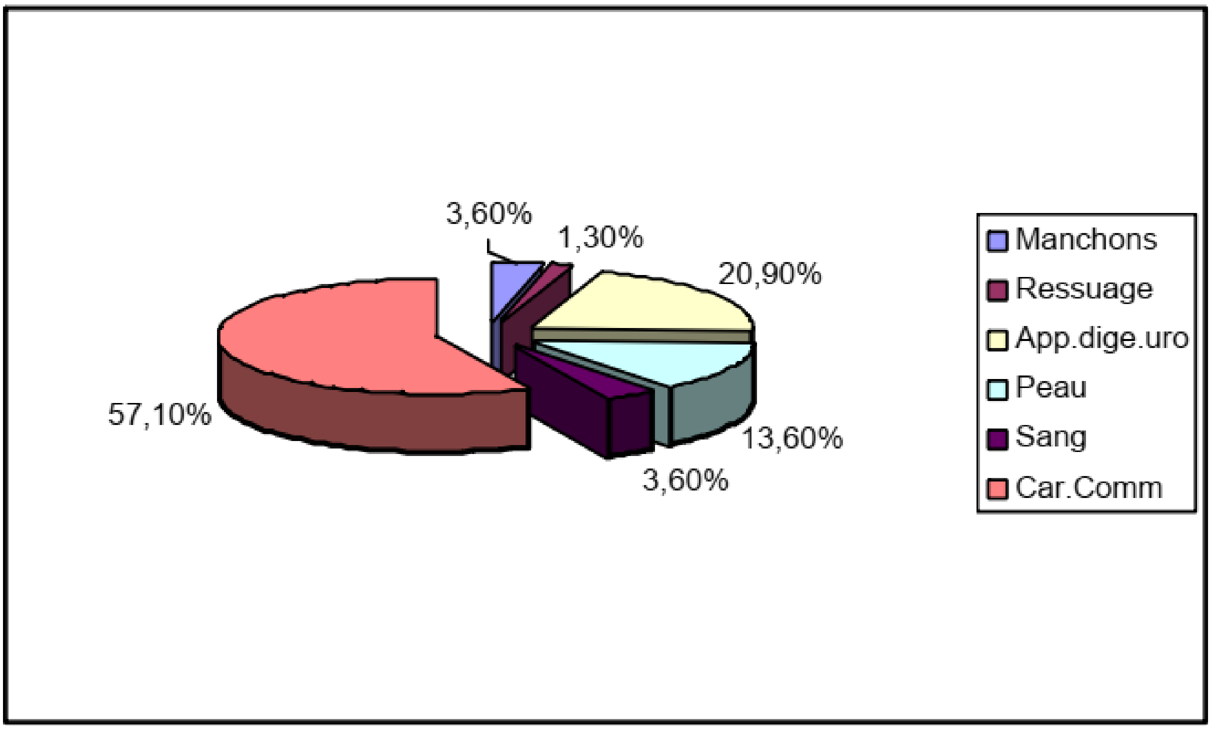

Figure 05: Meat yield of rabbit at 2.3 Kg (Ouhayoun, 1990).

3-3- Nutritional characteristics of rabbit's meat :

Meat, in general, consists mainly of water, proteins and lipids. It is an important source of micronutrients such as minerals and vitamins necessary for the proper functioning of the body (Combes and Dalle Zotte, 2005). However, it should be noted that the nutritional characteristics of rabbit's meat, as the other monogastric animals, are influenced by the nature of the fat contained in their diet. Rabbit meat has the lowest caloric value compared to other meats (Table 02), but according to Dalle Zotte and Szendrő (2011), this value mainly depends on the high protein content, which represents 80% of the energy value. Rabbit is the least fatty meat compared to that of pig (14.95g / 100g), beef (10.43g / 100g), chicken (10.43g / 100g) and lamb (16.15g / 100g), but it is comparable to that of calves (6.77g / 100g). In addition, the water content of the meat varies little from one species to another.

Table 02: Chemical composition (g) and energy value (Kj) of meat according to different species (per 100 g of meat).

	Pig	Beef	Calves	Chicken	Rabbit	Lamb
Total fat	14.95	10.43	6.77	15.97	5.55	16.15
Water	60 - 75.3	66.3 - 71.5	70.1 - 76.9	67 - 75.3	66.2 - 75.3	.
Energy	904	774	603	929	569	933
Protienes	18.95	20.71	19.35	18.33	20.05	18.04

Data from Salvini et al. (1998) per 100g of edible fraction.

3-3-1 -Lipid fraction :

Rabbit is a white meat that ranks among the meats with the lowest cholesterol compared to red meats such as pig (38.1 mg / 100 g); beef (45.2 mg / 100 g) and calves (45.7 mg / 100 g; Table 03). This is a good thing for rabbit meat and an interesting alternative for those who suffer from atherosclerosis. Also, the lipids in meat usually contain less than 50% of saturated fatty acids, (beef 45.2%, pig 38.1%, calves 45.7%, chicken 32.7%, rabbit 38.9%) and unsaturated fatty acids (mono and polyunsaturated ; Table 03).

Table 03: Content of the different types of fatty acids (% of total FA) and the cholesterol content (mg / 100 g) of Longissimus dorsi (Dalle Zotte and Szendrö, 2011)

	Pig	Beef	Calves	Chicken	Rabbit
	Mean ± σ	Mean ± σ	Mean ± σ	Mean ± σ	Mean ± σ
SFA	38.1 ± 2.50	45.2 ± 3.80	45.7 ± 5.40	32.7 ± 4.90	39.9 ± 4.4
MUFA	46.7 ± 6.10	43.5 ± 5.40	39.8 ± 5.50	35.4 ± 9.90	28.0 ± 4.10
PUFA	13.8 ± 6.90	8.79 ± 3.83	13.3 ± 7.80	27.4 ± 7.30	32.5 ± 6.10
EPA 20:5, n-3	0.14 ± 0.15	0.25 ± 0.23	0.41 ± 0.40	0.13 ± 0.06	0.15 ± 0.12
DHA 22:6, n-3	0.15 ± 0.17	0.07 ± 0.08	0.16 ± 0.10	1.01 ± 0.93	0.31 ± 0.31
Omega 6(n-6)	14.3 ± 6.20	7.55 ± 3.61	9.07 ± 6.10	26.2 ± 7.00	24.1 ± 5.60
Omega 3 (n-3)	0.72 ± 0.23	1.43 ± 0.92	2.14 ± 0.97	1.99 ± 1.05	5.5 ± 4.66
n-6 / n-3	21.9 ± 16.6	8.90 ± 7.30	6.61 ± 6.09	15.8 ± 5.4	7.02 ± 3.62
Cholesterol	62.7 ± 22.4	48.7 ± 8.10	52.3 ± 5.80	55.3 ± 4.6	47.0 ± 7.90

σ: the standard deviation.

Fatty acids (FAs) are lipid compounds that can be saturated, monounsaturated or polyunsaturated. Although it is slightly higher for rabbits than the amount found in chicken (32.7%), saturated fatty acids are significantly lower than those found in red meats: beef

(45.2%) and calves (45.7%).Furthermore, rabbit meat shows an omega 6 / omega 3 ratio equal to 7.2 (Table 03), lower than that of pig, beef and chicken, and comparable to that of calves. Indeed, according to Dall Zotte and Szendro (2011), the recommended dose of PUFAs in a healthy daily diet is between 5-10 (the ratio n-6 / n-3); but according to Simopoulos (2002) a lower ratio is more desirable to reduce the risk of chronic diseases. Linoleic and α-linolenic acids are named essential because the human body cannot synthesize them (Combes, 2004). Polyunsaturated fats are a big part of the diet for their multiple health benefits such as improving cholesterol and reducing the risk of cardiovascular disease (Hu and Willett, 2002). In fact, the study by Fedrigo et *al* (1999) demonstrated that the lipids in rabbit meat have the effect to doubled the amount of fatty acids capable of lowering blood cholesterol than that of fatty acids that increase blood cholesterol (it is a cholesterol-lowering effect).

3-3-2 -Mineral and vitamin fractions:

The mineral composition of a meat differs according to each species. That of rabbit's meat is characterized by a low level of sodium (Na), calcium (Ca) while the level of potassium and phosphorus are high compared to other meats (Table 04). Its sodium content is very low, 37 mg / 100g of meat, makes it particularly suitable in a low sodium diet (recommended against hypertension). Phosphorus is the second most abundant mineral in meats, and in that of rabbits with 222-230 mg / 100g. In comparison, chicken, calves, pigs and beef have lower phosphorus levels (180-200 mg / 100g, 170-214 mg / 100g, 158-223 mg / 100g and 168-175 mg / 100g, respectively).

Regarding the vitamin profile of rabbit's meat, it is close to that of chicken as shown in Table 1.6. In addition, pig is distinguished by its very high content of thiamine B1: 0.38-1.12 mg / 100g. However, the highest content of folic acid is observed in beef with 5-24 µg / 100g. Remember that folic acid, or vitamin B9, plays an important role in cell growth, especially in pregnant women. As for vitamin A, it is present in the form of trace both in rabbit meat and in that of other species. However, even if the level of selenium in animals depends on their diet, rabbit meat is a good source of selenium, a mineral with sought-after antioxidant activity.

Table 04: Composition of minerals and vitamins (mg) of different kinds of meat (per 100 g of meat)

	Pig	Beef	Calves	Chicken	Rabbit[1]
Ca	7 - 8	10 - 11	9 - 14	11 - 19	2.7 - 9.3
P	158 - 223	168 - 175	170 - 214	180 - 200	222 - 230
K	300 - 370	330 - 360	260 - 360	260 - 330	428 - 431
Na	59 - 76	51 - 89	83 - 89	60 - 89	37 - 47
Fe (assimilable)	1.4 - 1.7	1.8 - 2.3	0.8 - 2.3	0.6 - 2.0	1.1 - 1.3
Vitamin B1	0.38 - 1.12	0.07 - 0.10	0.06 - 0.15	0.06 - 0.12	0.18
Vitamin B2	0.10 - 0.18	0.11 - 0.24	0.14 - 0.26	0.12 - 0.22	0.09 - 0.12
Vitamin BP	4.0 - 4.8	4.2 - 5.3	5.9 - 6.3	4.7 - 13.0	3.0 - 4.0
Vitamin B6	0.50 - 0.62	0.37 - 0.55	0.49 - 0.65	0.23 - 0.51	0.43 - 0.59
Acide Folique (µg)	1.00	5 - 24	14 - 23	8 - 14	10
Vitamin E	0 - 0.11	0.09 - 0.20	0.17 - 0.26	0.13 - 0.17	0.01 - 0.40
Vitamin D (µg)	0.5 - 0.9	0.5 -0.8	1.2 - 1.3	0.2 - 0.6	Trace

[1]Parigi Bini et *al*. (1992) Translated from Combes and Dalle Zotte (2005) and Dalle Zotte (2000)

3-3-3 -Essential amino acids :

Nine amino acids are essential for the body because it cannot synthesize them. Thus, when provided by food, it covers the needs necessary for the growth proteins for the body. Proteins are composed of one or more chains of amino acids (AA) and Dalle Zotte (2000) observed that the composition of essential amino acids (EAA) varie between species, according to anatomical regions and also within the same species. The rabbit contains each of the nine amino acids essential for the proper functioning of the organism and in more or less greater quantity than that of red meats. This high and balanced EAA content gives rabbit meat proteins of high biological value (Table 05).

Table 05: Composition of essential amino acids of different meats (g / 100 of meat)

	Pig	calves	Chicken	Rabbit[1]
Lysin	1.29	1.69	1.66	1.85
Meth-Cyst	0.60	0.74	0.77	1.1
Histidin	0.49	0.59	0.52	0.53
Threonin	0.74	0.85	0.85	0.16
Valin	0.81	1.02	0.89	0.99
Isoleucin	0.77	0.93	0.92	0.99
Leucin	1.20	1.57	1.6	1.81
Arginin	0.97	1.23	1.22	1.23
Tyrosin	0.54	0.68	0.66	0.73
Phenylalanin	0.63	0.8	0.73	1.03
Tryptophan	0.20	0.22	0.21	0.21

Combes et Dalle Zotte (2005)

3-4- Muscle fibers :

In the rabbit, there are two glycolytic muscles (Longissimus lumborum and Psoas major), two more oxidative (the semimembranous proprius and the soleus) and one intermediate lateral gastrocnemius (Alasnier et *al*., 1996). Dalle Zotte (2000) demonstrated that Longissimus lumborum is the most glycolytic with a pH_u equal to 5.5 and the soleus, the most oxidative with a pH_u equal to 6.4. However, in general, the most oxidative muscles are located in front of the carcass; the least oxidative are those of the thigh according to Ouhayoun and Delmas (1988).

3-5- Quality of the rabbit's meat:

The quality of the meat is constantly changing and the consumer wants to be sure of its safety. According to Lebret et *al* (1996), the term quality of meat generally includes four components, which are the organoleptic, chemical, nutritional and microbiological qualities. However, for the consumer, the quality of a meat is reflected in its color, tenderness, juiciness and flavor. In addition, according to Faucitano and Geverink (2008), it is also linked to pre-slaughter stress and its effect on muscular energy metabolism.

3-5-1 pH:

Meat pH is a measure of muscle acidification through the production of the after dead lactic acid via glycolysis in the absence of respiration and circulation. It is used to assess the quality of meat and its conservation period (Korkeala et *al*., 1986). According to studies by

Hocquette et *al*. (2000), the pH of meat after the death of the animal influences the color, the water retention capacity, the juiciness and especially the tenderness of the meat. Generally, the pH of the muscle is measured one hour (pH_1) and 24 hours (ultimate pH: pH_u) after the death of animals. This latter is described as ultimate, since it practically does not change thereafter. At the time of death, the pH of the muscle is 7.0-7.2, but during the transformation of the muscle into meat and the conversion of glucose, glycogen, etc. in lactic acid an ultimate pH is at 5.5 to 5.7. Considerable differences in pH can be observed between different muscles in the same carcass. For example, in rabbits, the pH_u of Longissimus dorsi is much lower compared to that of Biceps femoris, which is a function of its low glycolytic potential (Hulot and Ouhayoun, 1999).

3-5-2 Colour:

Color is one of the main quality criteria for food products, as it influences consumer choice and is affected by the pH_u of the meat. In fact, meats with a high pH_u absorb a lot of light and have a dark color, while a low ultimate pH results in low penetration of light into the muscle. Thus giving a lighter meat, a decrease in the water retention power of the muscle and therefore, significant losses of exudate occurring during the conservation of the meat (Interbev, 2006). Therefore, it is important that the color of the meat is stable, as it is a determining factor in the purchasing act of the consumer. The latter looks for a clear nitrop pink color, neither too dark and, above all, homogeneous (Lebret et *al*., 1996).

3-6- Water loss and cooking loss :

Muscle contains around 75% water, the majority of which is retained within myofibrils (Hughes et *al*., 2014). Meat exudate is formed by the loss of muscle fluid without mechanical force.

4 -Nutrition of rabbits :

4-1 Nutritional needs and recommendations for rabbits after weaning :

After weaning, the rabbit continues to grow and its food requirements increase in quantity and quality. Therefore, it is necessary to provide a complete and granulated food. This food must be formulated to cover the nutritional requirements of these animals and allow them to maximize their growth potential with a low feed conversion rate.

In formulation of rabbit's foods, the determination of the nutritional requirements and the nutritive value of raw materials are the most important. Many researchs and experiments were done to evaluate and improve this domaine passing by Lebas (1975) to NRC (1977), Lebas (1979), l'INRA (1984 and 1989), Lebas et *al* (1984), Lebas (1989), Maertens (1992), Gidenne (1996), Lebas et *al* (1996), Gidenne (2000, 2003), Lebas (2004) arriving to De Blas and Mateos (2010). Nowadays, other several parameters fall within the definition of "performance" including the effects of food on the health of animals (Coleman et Moore, 2003; Maertens, 2009a et 2010, Xiccato et Trocino, 2010). Rabbits need nutrients for growth and physiological activities as energy, protiens, fat, fiber and minerals.

4-1-1 Energy :

The main sources of energy in rabbit nutrition are the carbohydrates. The important carbohydrates in rabbit feed are starch (digestible) and fibre (indigestible). Starch provides energy that is readily available and easily digestible while fiber; are digested by the bacterial population in the hidgut. If the health conditions are respected and the food resources are sufficient, then rabbits ingest enough food to meet their energy needs. The energy requirements for maintenance of growing rabbits are on average 430 kJ / day / kg $LW^{0.75}$ (Xiccato and Trocino, 2010), but vary considerably depending on the breed of 381 kJ / day $LW^{0.75}$ for New Zealand White rabbits at 552 kJ / day $LW^{0.75}$ for Giant Spanish rabbits (De Blas et *al*., 1985; Partridge et *al*., 1989). However, diets must meet the rabbit's requirements in energy because low energy diets cause an increase in caecotrophy production and ingestion (Jenkins, 1999). In other hand the increase in the level of dietary energy intake also affects body gain composition (de Blas and Wiseman, 2010).

4-1-2- Protein:

Protein is the fundamental component of animal tissue (muscles, cell tissue), certain hormones and all enzymes. Amino acids are the building blocks of protein. When speaking about protein nutrition in rabbits, crude protein (CP) and apparent DP are the most commonly used units, for which both requirements and raw material composition (Villamide et *al*., 1998; Maertens et *al*., 2002). Rabbits have specific amino acid requirements and apparent faecal and true ileal digestible amino acids would be more reliable units. Besides the maximization of nitrogen retention, needs a correct dietary supply of protein and amino acids in growing and reproducing rabbits (Maertens et *al*., 2005; Xiccato et *al*., 2005a, 2006; Calvet et *al*., 2008).

In growing rabbits, protien requirements of maintenance are estimated to be 2.9 g DP day per kg $LW^{0.75}$ (Partridge et *al*., 1989; Fernández and Fraga, 1996; Motta Ferreira et *al*., 1996; Fraga, 1998).While growth requirements vary according to the growth rate. The dietary protein levels recommended for growing rabbits range from 150 to 160 g CP kg. In recent studies, the standard CP concentration of commercial diets seems to exceed rabbits' requirements around weaning and during growth (Maertens et *al*., 1997; Trocino et *al*., 2000, 2001; García-Palomares et *al.*, 2006a, b; Eiben et *al.*, 2008).

About amino acid requirements, the literature is rather old and restricted to the most limiting amino acids in the diet (lysine, sulphur-containing amino acids, threonine and arginine). Therefore, the amino acid levels actually recommended are still those provided by Lebas (1989) and revised by de Blas and Mateos (1998). In growing and non-reproducing rabbits, it is recommended a minimum level of 5.4 g total sulphur-containing amino acid kg (4.0 g digestible amino acid kg) to obtain adequate productivity.

4-1-3 Fat :

Fat is considered as an energy source in animal's foods, it contains roughly 2 times more energy than carbohydrates. The addition of fat in rabbit's diet also increases palatability, reduces fines and helps in the absorption of fat-soluble vitamins (A, D, E and K) in the digestive system but it is limited (<2% ; Maertens, 1998). There for fat could be used to stimulate growth or the immune system and improve health status in fattening rabbits (Xiccato et *al.*, 2003, Maertens et *al.*, 2005). Nutritional fat recommendations for growing rabbits are estimed between 20 to 25 g / kg of food between weaning and 42 days of age, and 25 to 40 g / kg of food in the post-weaning period (Lebas, 2004).

4-1-4 Fiber :

Fibers are one of the main constituents of commercial food for growing rabbits, with an incorporation rate between 35 and 50% of the total digestible fiber in food. In rabbit's food, the most important fiber fractions are cellulose, which corresponds to the difference between ADF and ADL, and hemicelluloses, which correspond to the difference between NDF and ADF. It is widely demonstrated that an increase in the level of fiber in rabbit's food has a beneficial effect on health. However, to optimize the functioning of rabbit's breeding system, it is necessary to compromise between growth performance and animal health

(Gidenne, 2000). Current recommendations for fiber levels in foods for growing rabbits are shown in Table 06.

Table 06: Nutrition recommendations of fiber and starch for fattening rabbits (g / kg raw food, corrected for a dry matter content of 900 g / kg, Gidenne, 2000).

Ingredients (g/Kg)	After weaning (until 45 days of age	End of fattening
Acid detergent fiber (ADF)	≥190	≥170
Lignin detergent fiber (ADL)	≥55	≥50
Cellulose (ADF-ADL)	≥130	≥110
Ratio Lignins / Cellulose	≥0.4	≥0.4
Hémicellulose (NDF – ADF)	≥120	≥100
NDF / ADF	≥1.3	≥1.3
Amidon	≥140	≥180

4-1-5 Minerals :

Minerals are grouped into two categories – macro minerals and micro minerals. Macro minerals include calcium, phosphorus, sodium, magnesium and potassium which are required in grams per day. Micro minerals include copper, zinc, manganese, iron, iod, selenium and cobalt, which are required in milligrams per day. The most minerals used in formulation of rabbit's foods are calcium, phosphorus and sodium, In order to ensure proper skeletal development, the recommended calcium, phosphorus and sodium contents are 7 to 8, 4.0 to 4.5, and 2.2 g / kg, respectively (Lebas, 2004).

4-1-6 Vitamins :

Vitamins are divided into two categories – fat-soluble and water-soluble. Vitamin B and vitamin C are water-soluble; vitamins A, D, E and K are fat-soluble. The vitamin requirements of growing rabbits are generally lower, with the exception of vitamin C, nicotinamide and choline (Lebas, 2004). The interest of a higher rate of incorporation of vitamin C into rabbit's food in growth period is linked to the fact that vitamin C reduces stress (Mateos et *al.*, 2010). Furthermore, Vitamin C acts either as a pro-oxidant or antioxidant depending on the level of vitamin E in tissues (Chen, 1988). Nicotinamide intake is also higher in growing rabbits because of its favorable effect on intestinal health (Briend et *al.*, 1993).Choline is necessary for optimal growth and can be synthesized by the animal, but supplementation in food can improve performances (Mateos et *al.*, 2010).

4-2 Feed behaviour :

In the first two weeks of life, milk is the only source of nutrients for young rabbits. Deos visits her youngs at nest once a day, and milk feeding lasts only 3 to 4 minutes (Hudson et *al*., 1996). The young rabbits ingest 10 g of milk the first day of life than increase its consumption gradually to reach about 30 g / d at 22 days of age.

In the most rabbit farms, weaning is done around 5 weeks of lactation, changing either the mother or the rabbits from cages. During this transition, the nutritional composition of the diet changes gradually. The ingestion of solid food begins around 18 days of age. The age and quantity of solid food ingested at the beginning vary considerably between litters, which is probably related to the quality and quantity of milk available for the rabbits.Therefor, rabbits form largest litters, 10 in comparison with 4 rabbits / litter, begin to eat solid food earlier (Gidenne et Fortun-Lamothe, 2002a). At 21 days of age, the proportion of dry matter in the daily ration of a rabbit that comes from milk is still very high (77%, Prud'hon et *al*., 1975). After the peak of lactation about 18 to 20 days of age, the milk production decreases rapidly and the nutrients ingested come mainly from the solid diet. At 35 days of age, solid food intake can reach up to 47 g / day (Orengo and Gidenne, 2007) (Figure 1).

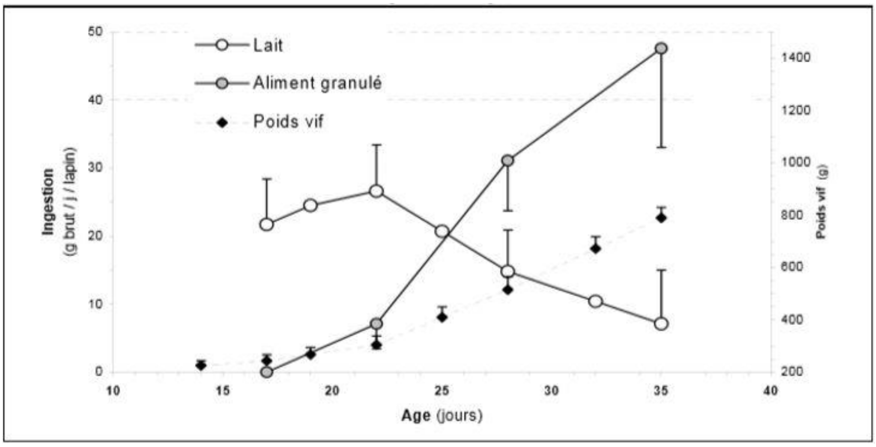

Figure 06: Growth, ingestion of milk and solid food in the rabbits, between 14 to 35 days of age (Orengo and Gidenne, 2007).

At weaning, young rabbits fed frequently as they fed 30 to 40 solid or liquid meals per 24 hours (Johnson-Delany, 2006). With age, the time spent for feeding decreases until

1:30 to 2:15 a day, divided into 23 to 33 meals (Prud'hon et *al*., 1972). Most meals and feed intakes take place during the night (Lebas et *al*., 1996; Martignon et *al*., 2009). While the number of meals taken during the day period decreases. This period in the morning would be explained by the practice of caecotrophy, which usually occurs between 8 and 14 h (Bellier et *al*., 1995). Caecotrophs represent either 15 to 35% of feed intake or 10 g / day to 55 g / day of fresh matter ingested between 1 and 2 months of age (Lebas et *al.*, 1996).

The composition of food distributed to rabbits, including their energy and protein content, plays a role in the quantity ingested. Food consumption is reduced when the food has a high-energy content, and tends to increase when it has a high level of protein (Lebas et *al.*, 1996). Food consumption is related to the physiological stage of the animal, the stage of production and the ambient temperature. The rabbit regulates its level of ingestion according to its energy needs.

4-3- Dietary strategies:

In rabbit's breeding farmers used tow strategies in feeding animals, restriction and adlibitum strategies. Dietary restriction is a common strategy used in rabbit rearing after weaning to improve feed efficiency and health status in growing rabbits (Gidenne et *al.*, 2012). During a dietary restriction, the ingestion profile of rabbits differs significantly from that observed in animals fed adlibitum (Martignon et *al.*, 2009). Thus, when the food is distributed once a day, 1/3 of the quantity distributed is ingested within 2 hours after the distribution (Martignon et *al*., 2009) and the entire ration is ingested in less than half a day. Contrary, in animals fed ad libitum, the rabbits ingest in multiple meals of 1h30 - 2h00 between 4 and 13% of the total quantity consumed on the day. Limiting the ingestion has a negative effect on growth; however, this reduction is not directly to the reduction of intake. Thus, with a reduction in ingestion of 20%, growth rate decreases on average by 15.6% (Gidenne et *al*., 2012).

The ratio of water to food is twice higher in rabbits rationed at 65% as in those fed ad libitum, because during a dietary restriction, the number of passages of rabbits by pipette is reduced (-19%) while the quantity of water ingested is higher (Boisot et *al.,* 2005). These authors have also shown that pipette access limited to 1 hour / day can reduce feed intake by 35%.

4-4- Feed formulation :

Feeding is the principal factor in rabbits breeding; therefore, we must be careful in formulating diets. Furthermore, rabbit diets must be formulated to allow a sufficient nutrient intake to meet the high nutritional requirements for animals. So it is necessary to respect the balance of nutrients and the quality of raw materials used in fabrication of food. In other hand, the cost of diets and its effect on meat quality and pathology should also be considered.

4-4-1- Fiber level:

In formulating rabbit's diets the principal factor, that we must be careful on it is the level of fiber because high fibre diets decrease the average daily gain and feed conversion rate (de Blas et *al.,* 1995; Feugier et *al.*, 2006). High-fibrous diets are frequently formulated to limit the incidence of diarrhea but several studies have shown that diets contains high level in ADF increases mortality rate in fattening rabbits (Gutiérrez et *al.*, 2002; Romero et *al.*, 2009). Conversely, a minimal content of dietary fibre is required to decrease total and caecal mean retention time and to maximize DE intake and weight gain.

The type of fiber plays a principal role in formulating of diets. Alfalfa hay is the most used as source of fiber in rabbits foods because of its high content in digestible fiber, which allows an adequate transit time of the digesta and a balanced growth of the caecal flora. Beside, highly lignified sources of fibre decrease the digestibility of energy and caecal fermentative activity (García et *al*., 1999). However, soluble fiber at moderate levels (120 g soluble NDF kg) has a positive effect in rabbits by improving immune response and reduce the deterioration of mucosa after weaning, pathogen proliferation in the gut and fattening mortality (Fabre et *al*., 2006; Gómez-Conde et *al*., 2007).

4-4-2- Level and Source of Protein:

Total protein requirements are expressed as a ratio between DP and DE in formulating diets of rabbits. Many works were studied by De blas et *al*. (1981) and Fraga et *al.* (1983) about the variation of this ratio and its effect on performances in fattening rabbits. Maximal DE intake and average daily gain were obtained for diets with a DP/DE ratio of 10 g DP / MJ DE. Low DP/DE values (<9.5 g /MJ) causes a decrease in water and protein and an increase in body fat. As for fiber the type of protiens used affect performances in rabbits where its was found that the reduction in dietary protein content or the use of highly digestible protein sources decreases ileal protein flow and reduces the proliferation of pathogens and mortality during the fattening period (Gutiérrez et *al.*, 2003; García-Ruiz et *al.*, 2006; Chamorro et *al*., 2007).

4-4-3- Fat Supplementation:

The addition of different sources of fat (tallow, lard, deodorized oleins or sunflower oil) in diets for fattening rabbits has been studied (Partridge et *al*., 1986; Santomá et *al.*, 1987; Fernández and Fraga, 1992). The results show an increase in digestible protein (DP) content with fat addition. Also, fat inclusion had a positive effect on energy digestibility (5% on average) and feed efficiency (7%), but not on growth rate, as feed intake decreased by 6%. No interaction was found between the type and level of supplemental fat. So that, the value of fat addition to fattening feeds should be established on an energy-cost basis taking into account the effects of fat quality on carcass quality and pellet stability.

4-5- Interaction between feeding and pathology:

More recently, the importance of the relationship between nutrition and the health status of growing rabbits has been underlined by several authors, including the role of the caecal ecosystem (Gidenne et *al.*, 2008), and that of protein intake (Carabano et *al.*, 2009). In commercial rabbit husbandry, various health problems related to feeding, intestinal pathology and respiratory diseases are the predominant causes of morbidity and mortality. Moreover, digestive disorders after weaning induced many problems in rabbits as enteritis and the appearance of epizootic rabbit enteropathy (ERE) (Koehl, 1997) leading for high rates of mortality until 11 and 12%. The main symptom observed in rabbits affected is diarrhrea that occurs in about 0.90 % of enteritis cases (Licois et *al*., 1992). This problem may be related to the diet because a low fiber diet may reflect a higher antiperistaltic activity of the proximal colon induced by the high proportion of fine particles in a low-fibre diet.

Fiber incorporation and its nature in the diet affect the health of young rabbits (Gidenne et *al.*, 2010a). In addition, the interaction between the starch content of the diet and dietary fiber must be taken into account during formulation (Marlier et *al.*, 2003), although a recent experiment shows that of these two components, only the fiber content of the diet would influence the digestive health of animals (Gidenne et *al.*, 2004). In healthy growing animals, when the fibre intake is too low (<8–11 g ADF kg/ LW/ day), the caecal fibre level decreases while the starch concentration remains low (around 15–40 g /kg), and there are no consistent changes in the concentration of the fermentation end products (ammonia, VFA) and caecal pH. These changes determine the greater incidence of digestive troubles (mainly diarrhoea).

For protiens, an excess food alters the health status of animals and may favor the development of pathogens, such as *Clostridium* or *E. coli* (De Blas et *al*., 1981; Cortez et *al*. 1992). Also, Gidenne et *al*. (2001b) showed that a high level of protein incorporation as a substitute for digestible fiber increased the risk of diarrhea. On the other hand, a digestible fiber / total nitrogen content ratio more than 1.3 appears to be protective against the ERE (Gidenne et *al.*, 2001b). In addition, an increase in the nitrogen content of the ceacum improves the developpement of pathogenic bacteria, such as *Clostridium* (Cortez et *al*., 1992).

4-6- Food sources used in rabbit feeding:

Feeding represent about 60% of production costs in rabbits farms (Gidenne et *al.*, 2013). This cost tends to increase due to the rise in the price of raw materials (Braine and Coutelet, 2012). The type of feeding depends on the type of rabbit's system production, traditional, intermediate or commercial (Colin et Lebas., 1996). The traditional system was based on fruits, vegetable, dry bread, hay and straw, tree leaves and sometimes barley or wheat bran. This type of breeding is generally intended for self-consumption. However, in rational system the complete granulated feed is used exclusively with a real economic impact.

The classic rabbit diet in rational breeding is based mainly on 3 complementary sources in a standardized model. Soybean meal for protein, cereals including corn for energy and alfalfa for fiber. This latter is the most commonly used as a source of fiber. Other sources are used for the supply of fibers, such as flour mill products, wheat straw and some pulps (beet, citrus, etc.).

Fourrages can be incorporated at 30% and 50% in rabbit pelleted food (Fernandez-Carmona et *al.*, 1998, Maertens, 2009b). But, it is known that foourags have an effect on organoleptic characteristics of rabbits meat PUFA (Combes and Cauquil, 2006), health and welfare (Liu et *al.*, 2010).

In previous studies, it twas mentioned the use of different raw materials and co-products used in rabbits diets (Lebas, 2004). Cereals and their co-products have been mentioned with their different incorporation rates. Other co-products used as sources of energy have also been classified by mentioning the incorporation rates and the precautions inherent in their use. The standardized model based on the use of conventional raw materials such as corn, soybean meal and alfalfa has been called into question since the American embargo on soybean on Europe in 1973. This model then began to be modified according to the availability of new sources, hence the emergence of the concept of alternative sources to replace these conventional materials.

4-7- Alternative raw materials in rabbit production :

The high price and sometimes the unavailability of certain imported raw materials is the main obstacle to the development of rabbit production. Therefor, the research of alternative raw materials and local co-products would be a plausible way for the autonomy of this sector. Algeria is a concrete example in this case because of the prices of these imported inputs, which have a big weight on the economy of the country. This concept of alternative sources that meets the requirements of sustainable agriculture is a real environmental and economic challenge in rabbit production.

Many works and studies about the valorization of local resources in Algeria was started as early as the beginning of the 1990s (Berchiche and Lebas 1990, 1996, 1999, Kadi et *al*., 2011, Kadi 2012, Lounaouci et *al*., 2009, 2011 and 2014, Guemour et *al*, 2010 ... etc). Fibrous co-products with an appreciable protein content constituting interesting potential sources for rabbit feeding (Carabano and Fraga, 1992) are available in the Mediterranean countries, particularly in Algeria.

The brewery is widely available but its nutritional value in rabbits is poorly studied (Fernandez Carmona et *al*., 1996, Maertens and Salifou, 1997). Berchiche et *al*. (1999) have tested the effect of substitution of soybean meal by brewery.

Other co-products of agri-food industries such as milling products have been the subject of studies, particularly on zootechnical performances and their variability (Lakabi et *al.*, 2008; Boudouma, 2009; Lounaouci et *al*., 2011, 2014). But, data on their nutritional value in rabbits are rares. Olive co-products are widely available in Algeria, which has been already tested in substitution for alfalfa as a source of fiber in rabbit’s diets (Kadi et *al.*, 2004). Guemour et *al*. (2010) have tested also the effect of incorporation of grape pomace in rabbit’s diets, which is widly available in our country.

4-8- Nutritional value of raw materials used in rabbit feeding :

The estimation of the nutritional value of raw materials is an essential step in the formulation of rabbit's diets. It allows a wide use of co-products and alternative raw materials in the formulation of complet feed for rabbits. Table 07 present the nutritive value of 55 raw materials commonly used in rabbits (Villamide et *al*. 2010).

Table 07: Composition and nutritional value of raw materials commonly used in rabbits (g/ kg), Villamide et *al* (2010).

	DM	Ash	CP	EE	CF	NDF	ADF	ADL	Soluble fibre	ST	Sugar	Lys	Met	SAA	Thr	Ca
Cereals																
Barley	880	22	103	20	46	175	55	9	25	510	25	3.9	1.7	4.2	3.6	0.6
Maize	880	12	82	35	19	95	25	5	1	640	15	2.3	1.7	3.5	2.9	0.2
Oats	880	26	106	51	111	280	135	22	32	370	15	4.4	1.9	5.3	3.7	1
Triticale	880	18	110	16	23	125	31	9	11	570	30	3.9	1.9	4.6	3.6	0.5
Wheat	880	16	108	18	22	110	31	9	3	600	25	3.3	1.8	4.5	3.4	0.4
Cereal by-products																
Maize gluten feed	900	67	215	43	78	312	94	12	63	180	20	7.1	4.1	9	8	1.7
DDGS	900	60	253	90	81	316	89	12	66	105	10	6.6	5.1	8.9	8.9	1.4
Malt sprouts	900	61	232	19	126	378	139	18	30	110	70	10.8	3.1	6	8.1	2.1
Rice bran	900	90	135	153	81	211	101	36	11	270	30	5.9	2.1	4.4	5.3	1.2
Wheat bran	880	50	150	34	95	405	118	35	1	190	50	5.9	2.4	5.5	4.8	1.5
Wheat feed	880	40	140	40	50	271	77	24	29	270	90	5	2.5	7	5	1
Wheat shorts	880	36	158	36	70	326	100	27	34	240	50	6.3	2.6	5.7	5	1.4
Other energy concentrates																
Beet molasses	750	86	105	–	–	–	–	–	109	–	450	0.4	0.5	1	0.6	2.2
Cane molasses	750	98	45	–	–	–	–	–	137	–	470	0.2	0.2	0.4	0.5	7.4
Cassava 60	880	57	26	7	48	124	77	21	48	600	18	1	0.3	0.7	0.8	3
Cassava 65	880	57	26	7	44	95	68	20	24	650	21	1	0.3	0.7	0.8	2.5
Cassava 70	880	35	26	7	31	80	50	14	7	700	25	1	0.3	0.7	0.8	2
Glycerine	900	45	–	4	–	–	–	–	–	–	853	–	–	–	–	0.4
Legume and oil seeds																
Faba bean	880	33	257	13	77	123	89	8	29	390	35	16.8	1.8	5	9.2	1.2
Lupin	880	35	326	70	128	210	155	15	179	–	60	15.9	2.5	7.3	11.6	2.3
Peas	880	30	220	12	57	120	70	4	18	435	45	16.3	2.2	5.4	8.4	1
Rapeseed	900	41	189	396	81	181	124	49	43	–	50	11.5	4.2	9.2	8.7	4
Soybean	900	47	369	193	56	117	73	8	99	–	75	23.3	5.2	11.4	14.4	2.5
Oil meals																
Coconut cake	900	60	202	74	125	447	235	55	24	–	93	5	3	6.1	6.6	1.4
Palm cake	900	40	147	84	178	605	372	110	4	–	20	4.8	2.8	5	4.6	2.1
Rapeseed meal	900	68	361	25	121	277	189	86	79	–	90	19.4	7.6	16.2	15.7	7
Soybean meal 44	900	68	432	18	77	161	100	8	141	–	80	27.2	6	12.5	16.8	2.9
Soybean meal 46	900	63	450	18	63	132	82	6	157	–	80	28.4	6.3	13.1	17.6	2.9
Soybean meal 48	900	61	468	18	50	124	65	5	149	–	80	29.5	6.6	13.6	18.3	2.9
Sunflower meal 28	900	68	279	27	252	428	302	101	48	–	50	10	6.7	12	10.3	3.5
Sunflower meal 32	900	68	306	23	225	383	270	90	70	–	50	11.2	7.4	13.1	11.3	3
Sunflower meal 36	900	68	342	19	180	306	216	72	115	–	50	12.5	8.2	14.7	12.7	2.5
Oils and fats																
Animal fat	995	–	–	990	–	–	–	–	–	–	–	–	–	–	–	–
Olein	995	–	–	990	–	–	–	–	–	–	–	–	–	–	–	–
Rapeseed oil	995	–	–	990	–	–	–	–	–	–	–	–	–	–	–	–
Soybean oil	995	–	–	990	–	–	–	–	–	–	–	–	–	–	–	–
Sunflower oil	995	–	–	990	–	–	–	–	–	–	–	–	–	–	–	–
Fibrous feedstuffs																
Lucerne meal 12	900	90	126	23	297	475	371	83	156	–	30	5.4	1.9	3.4	5.2	14
Lucerne meal 15	900	99	153	32	261	418	326	73	168	–	30	6.6	2.3	4.1	6.3	15
Lucerne meal 18	900	99	180	36	216	346	270	60	209	–	30	7.7	2.7	4.9	7.4	16
Beet pulp	900	72	90	10	180	428	212	18	240	–	60	5.3	1.9	3.1	4.4	7.6
Cacao hulls	900	80	164	50	183	390	300	140	216	–	–	7.5	1.5	3.5	6	3
Carob meal	900	32	47	5	78	289	248	138	96	7	424	1.6	0.9	1.5	1.7	4.5
Citus pulp	900	67	59	27	133	220	155	16	297	–	230	2	0.7	1.5	2	15.9
Flax chaff	900	76	102	35	315	455	310	110	232	–	–	3	0.5	1	1.5	18
Grape pomace	900	81	117	54	280	560	480	300	68	–	20	4.9	1.7	3.5	3.7	7
Grape seed meal	900	36	99	14	441	730	650	550	21	–	–	4	1.5	3.5	2	6
Grass meal	900	80	150	30	225	460	260	50	100	–	80	6	2	3.5	5.5	7
Olive leaves	900	72	90	40	200	455	318	177	153	–	90	–	–	–	–	11
Rice straw	900	162	60	5	295	585	340	22	88	–	–	–	–	–	–	–
Soybean hulls	900	46	122	20	355	588	426	21	114	–	10	7	1.4	3.4	4.6	5
Sunflower hulls	900	34	54	40	468	693	562	202	69	–	10	2.3	1.2	2.5	2.3	4
Wheat straw	900	61	36	12	395	750	474	80	36	5	–	–	–	–	–	3.8
Wheat straw treated	900	73	32	8	365	694	444	75	88	5	–	–	–	–	–	4.3
Whole maize plant (dehydrated)	900	36	72	25	126	360	153	10	57	330	20	2.5	0.9	1.7	2.6	3

– no analytical data available; AFD, apparent faecal digestibility; AID, apparent ileal digestibility; Ca, calcium; Cl, chlorine; nitrogen retention; Met, methionine; Mg, magnesium; Na, sodium; P, phosphorus; SAA, methionine plus cystine; ST, starch; (NaOH or KOH).

P	Na	Cl	Mg	K	CPd	DE (MJ kg^{-1})	MEn (MJ kg^{-1})	AFD lys	AID lys	TID lys	AFD met	AID met	TID met	AFD thr	AID thr	TID thr
3.6	0.2	1.4	1.3	5.1	0.67	12.90	12.50	0.66	0.62	0.80	0.75	0.74	0.87	0.55	0.41	0.70
2.5	0.1	0.5	1.1	3.2	0.65	13.10	12.75	0.64	0.63	0.80	0.73	0.71	0.86	0.53	0.38	0.69
3	0.2	0.7	1.3	4	0.73	10.90	10.45	0.72	0.70	0.82	0.80	0.78	0.90	0.63	0.50	0.75
3.4	0.1	0.5	1.2	4.2	0.75	12.90	12.40	0.74	0.72	0.87	0.82	0.80	0.91	0.65	0.53	0.76
3.5	0.2	0.6	1.2	4.1	0.77	13.10	12.65	0.76	0.75	0.89	0.86	0.83	0.92	0.68	0.56	0.78
8.6	2.2	2.2	3.8	9.7	0.70	11.40	10.65	0.72	0.71	0.84	0.77	0.69	0.89	0.59	0.45	0.73
7.3	0.5	2	2.9	9.7	0.70	12.70	11.75	0.70	0.69	0.84	0.77	0.69	0.89	0.59	0.45	0.73
6.6	0.6	4	1.5	11	0.75	10.80	9.90	0.75	0.74	0.87	0.82	0.73	0.91	0.65	0.53	0.76
16	0.6	0.8	10	16	0.65	12.45	11.95	0.64	0.63	0.80	0.73	0.66	0.86	0.53	0.38	0.69
10.9	0.3	0.8	4.4	11	0.74	10.30	9.75	0.74	0.73	0.86	0.81	0.72	0.91	0.64	0.51	0.76
9	0.2	0.9	4	10.2	0.79	12.35	11.75	0.80	0.79	0.89	0.85	0.76	0.93	0.70	0.59	0.79
10.5	0.3	0.8	4.2	13	0.77	11.20	10.55	0.78	0.77	0.89	0.83	0.74	0.92	0.68	0.56	0.78
0.2	8	10.8	0.5	39.1	0.70	10.65	10.25	0.70	0.69	0.84	0.77	0.69	0.89	0.59	0.45	0.73
0.9	2	20	4.2	45	0.60	10.10	9.90	0.59	0.57	0.77	0.68	0.62	0.84	0.47	0.30	0.65
1.2	0.4	1.1	1.4	12	0.50	12.05	11.95	0.47	0.46	0.70	0.60	0.55	0.79	0.35	0.15	0.58
1.1	0.3	0.7	1.1	7.5	0.50	12.50	12.40	0.47	0.46	0.70	0.60	0.55	0.79	0.35	0.15	0.58
1	0.3	0.7	0.9	4.4	0.50	13.10	12.95	0.47	0.46	0.70	0.60	0.55	0.79	0.35	0.15	0.58
2.4	16	29	0.1	*	–	14.98	14.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3	0.2	0.7	1.5	12.4	0.80	13.05	12.00	0.81	0.80	0.91	0.86	0.77	0.94	0.71	0.61	0.80
3.2	0.5	0.4	1.7	8.5	0.80	12.70	11.40	0.81	0.80	0.91	0.86	0.77	0.94	0.71	0.61	0.80
4	0.2	0.4	1.2	10.5	0.85	13.20	12.25	0.86	0.86	0.94	0.90	0.80	0.96	0.77	0.68	0.84
6	0.3	0.6	2.4	7.9	0.78	20.90	20.10	0.79	0.78	0.89	0.84	0.75	0.93	0.69	0.58	0.78
5.6	0.1	0.3	3	17	0.85	17.35	15.80	0.88	0.86	0.94	0.90	0.80	0.96	0.77	0.68	0.84
5.4	0.6	6.3	3	18.1	0.65	12.15	11.45	0.64	0.63	0.80	0.73	0.66	0.86	0.53	0.38	0.69
5.8	0.2	1.6	2.6	6.4	0.60	10.45	10.00	0.59	0.57	0.77	0.68	0.62	0.84	0.47	0.30	0.65
10	0.7	0.3	4.5	12.5	0.76	11.35	9.95	0.76	0.76	0.88	0.83	0.74	0.92	0.66	0.55	0.77
6	0.2	0.4	2.5	18	0.82	13.35	11.60	0.83	0.82	0.92	0.88	0.78	0.95	0.74	0.64	0.86
6.1	0.2	0.4	2.7	19.5	0.83	13.95	12.05	0.84	0.84	0.93	0.89	0.79	0.95	0.75	0.65	0.87
6.4	0.2	0.4	2.8	20.5	0.84	14.70	12.70	0.85	0.85	0.93	0.90	0.80	0.95	0.76	0.67	0.87
10	0.3	1.5	5	11	0.73	9.60	8.55	0.73	0.72	0.86	0.80	0.72	0.90	0.63	0.74	0.78
9.5	0.3	1.5	5	10	0.76	10.25	9.00	0.76	0.76	0.88	0.83	0.74	0.92	0.66	0.75	0.79
9	0.3	1.6	5	11	0.80	11.10	9.65	0.81	0.80	0.91	0.86	0.77	0.94	0.71	0.76	0.80
–	–	–	–	–	–	33.45	33.45	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	31.40	31.40	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	35.15	35.15	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	35.55	35.55	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	35.55	35.55	–	–	–	–	–	–	–	–	–
2.6	0.6	3.5	2	19	0.56	6.75	6.35	0.54	0.53	0.74	0.65	0.59	0.82	0.42	0.24	0.62
2.6	0.7	4.8	2.7	21	0.60	7.4	6.95	0.59	0.57	0.77	0.68	0.62	0.84	0.47	0.30	0.65
2.7	0.8	4.9	3	25	0.64	8.3	7.7	0.63	0.62	0.80	0.72	0.65	0.86	0.52	0.36	0.68
1	2	1	2.3	4.9	0.50	10.4	10.1	0.47	0.46	0.70	0.60	0.55	0.79	0.35	0.15	0.58
3.5	0.8	1.5	4	25	0.50	5.45	5.2	0.47	0.46	0.70	0.60	0.55	0.79	0.35	0.15	0.58
1	0.2	1.5	0.5	0	0.20	9	8.9	0.14	0.12	0.49	0.33	0.34	0.65	0.00	0.00	0.36
1.2	1	0.6	1.4	7.1	0.60	11.3	11.05	0.59	0.57	0.77	0.68	0.62	0.84	0.47	0.30	0.65
3	0.6	0.9	1	9	0.40	4.4	4.15	0.36	0.34	0.63	0.51	0.48	0.75	0.23	0.05	0.51
2	0.1	0.1	1.2	16	0.15	5	5	–	–	–	–	–	–	–	–	–
1.2	0.1	0.1	1	6	0.10	3.35	3.35	–	–	–	–	–	–	–	–	–
4	1	0.8	2	25	0.55	8.1	7.65	0.53	0.52	0.73	0.64	0.59	0.82	0.41	0.00	0.62
0.8	1.7	4.5	1.9	–	–	5.35	5.3	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	2.5	2.3	–	–	–	-	–	–	–	–	–
1.6	0.2	0.3	2	12.6	0.50	7.2	6.85	0.47	0.46	0.70	0.60	0.55	0.79	0.00	0.15	0.58
2	1	1	1.7	10.5	0.15	4.3	4.25	–	–	–	–	–	–	–	–	–
0.8	1.6	4.6	0.9	9.5	0.20	2.7	2.7	–	–	–	–	–	–	–	–	–
0.6	8.6	4.3	0.7	8.9	0.25	3.7	3.65	–	–	–	–	–	–	–	–	–
2.8	–	–	1.8	–	0.46	8.52	8.32	0.43	0.41	0.67	0.56	0.52	0.77	0.30	0.09	0.55

CPd , apparent faecal crude protein digestibility; K, potassium; Lys, lysine; MEn, metabolizable energy corrected for zero
Thr, threonine; TID, true ileal digestibility; DDGS, dry distillers grains and solubles; *, depends on the neutralizer used

The determination of the nutritional value of raw materials in rabbits has been the subject of several studies (Maertens and Lebas, 1989, Villamide 1996, Villamide et *al*., 2001, 2003, 2010, 2016).

The estimation of the nutritional value has a great interest in view of the large number of raw materials and co-products that can be incorporated into the rabbit diets, because of their great variability, which is related to their origin, chemical composition and their technological processes of production. Other way, some differences are observed according to the determination methods (Villamide et *al*., 2003). The composition and nutrient value tables of raw materials used for the formulation of foods for rabbits in rational breeding are regularly updated. The setting up of "Feedipedia" online tables since 2013, Tran et *al*. (2013) on the website (www.feedipedia.org) constitutes a complete and regularly updated database for nutritive value of animal's diets in the tropics and the Mediterranean region. It provides open access data on the nature, chemical composition and nutritional value of around 1400 livestock feed sources in the world.

4-9 Feed manufacturing :

Raw materials need to be processed by a combination of different treatments of individual processes to produce an acceptable final feed. This must satisfy all of the nutrient and physical presentation requirements of the animal, except for water. The manufacturing of each feed will always be conditioned by raw material composition and the nutritionist should take in account both individual and collective effects in the feed process itself. The initial process is weighing out according to the formula, followed by grinding for particle size reduction. Following the addition of premixes, homogenization of all the raw materials included in the formula is undertaken. Following an adequate mixing time, manufactured feed is obtained as a mash. However, rabbits are not fed mash diets and the feed therefore needs to be further processed by pelleting. Obtaining good quality pellets is one of the main targets of rabbit feed manufacturing and quality control of this step is essential.

4-9-1- Granulometry of compound feeds and functioning of the digestive tract:

The granulometry of food has specific effects in rabbits, related to the digestive particularities of this species (Lebas, 2000). The specific role of food particles in the digestive function of rabbits and more particularly in that of caecotrophy was demonstrated by

Bjornhag in 1972. According to Bouyssou et *al* (1998), during the formation of hard feces, the fine particles (1 mm) tend to be separated from the mass of the digestive contents in the proximal colon and to be pushed back towards the cecum along with a part of the liquids and soluble fractions. Indeed, authors have studied the role of granolometry of food on digestive function using non-pelleted foods. Particle size occurs mainly in the posterior segments of the gastrointestinal tract (caecum, colon) while easily degradable food particles have almost completely disappeared (Laplace et *al*., 1977). But a fine grinding increases the residence time of food in the digestive tract. However, a slowdown in transit is never favorable to animal health (Lebas et *al*., 1998). Table 08 illustrates the influence of pellet's diameter in rabbits between 5 and 12 weeks of age.

Table 08: Effect of pellets diameter on growth performances in rabbits between 5 and 12 weeks of age (lebas, 1991).

Characteristics	The diameter of pellets		
	2.5 mm	**5 mm**	**7 mm**
Feed intake (g/day)	117	122	131
Weight gain (g/day)	32.4	33.7	32.0
Feed conversion	3.7	3.7	4.1

4-9-2- Food presentation:

Rabbits are fed with dry and ground raw materials allowing their complementarity and the constitution of balanced whole foods. Unfortunately, rabbits do not tolerate the dust inevitably present in flours; therefore, it is generally preferable to granulate the mixtures (Blum, 1984). The pellet must have some dimension to limit the waste that young rabbits can do in particular. It will be 2.5 to 5 mm in diameter and 5 to 8 mm in length. According to Formunyam and Ndoping (2000), rabbits fed with long or short granules (diameter 1.1 cm length 2.1 cm or 6.1 cm have similar consumption and growth (DWG : 29.5 and 27.3 g / d) and significantly better than rabbits fed the food presented in flour (DWG of 21.9 g / d). However, the cost of waste in rabbits fed with long pellets or flour was about twice that for rabbits fed short pellets thus reducing the profit margin. Table 09 shows the effect of the presentation of the food on the growth performance of young rabbits by different authors.

Table 09: Effect of the presentation of the food on the growth performance of rabbits.

Authores	Presentation	Feed intake (g of DM/d)	Weight gain (g/d)	Feed conversion
Lebas (1973)	Flour	82	29.7	2.78
	Pellets	94	36	2.62
King and al (1980)	Flour	79	20.7	3.80
	Pellets	85	22.9	3.7
Machin and al (1980)	flour	102	26.5	3.8
	Pellets	104	33.1	3.3

5- Factors influencing appetite in rabbits:

5-1- Water :

If the water is dirty, even if it is thirsty, the rabbit does not drink (Djago and Kpodekon, 2000). Any limitation of the quantity of water required in relation to the needs leads to a reduction of at least a proportional consumption of the ingested dry matter and, consequently, an alteration of the growth performance of rabbits (Lebas, 2000).

5-2- Temperature :

Temperatures above 24 or 25 ° C reduce the feed intake of rabbits regardless of age or physiological status (Lebas, 2000). Thus, various studies carried out in the laboratory show that between 5 and 30 °C, the feed intake of the growing rabbit passes for example from 180 to 120 g for pelleted food and from 330 to 390 g per day for water (Lebas et *al*., 1996). According to Fielding (1993), appetite can decrease by more than half at a temperature of around 30 °C.

5-3- Health and physiological state :

A bad health leads to decreased appetite. In case of nutrient deficiency, the rabbit shows a depravity of the appetite and begins to gnaw the walls of the cage in an unusual way. If it lacks fiber, it can attack the fur of its congeners. During the last days of gestation in deos, the appetite is reduced by the development of fetuses.

6- Methods for determination and estimation of the nutrient value of raw materials in growing rabbits:

For compound food in rabbits, the determination of nutritional value of each raw material component is essential. In rabbit feeding, and for several years, data from other species (ruminants, horses, poultry and pigs) were used to determine the nutritional value of foods. Nevertheless, studies conclude that this analogy is imperfect because of the difference between these animals; because of its nutrition (fiber requirements) and digestive physiology (caecotrophy) in particular. So to obtain convincing results, it is necessary to exploit data obtained on rabbits (Maertens and Lebas, 1989). Therefore, methods for determination of the nutritive value of raw materials were formulated in the rabbit, such as the direct method, substitution method, multiple linear regressions and near infrared spectrometry. Prediction equations are developed to calculate the nutritional value of rabbit's foods (Maertens and Lebas, 1989; Villamide and Fraga, 1998; Villamide et *al*., 2009; Lebas, 2013). Moreover, this is the most common procedure in rabbit feeding in growth period.

6-1- In-vivo measurements :

6-1-1- Direct method:

It is the most widely used method of evaluating complet foods. However, for raw materials alone, it should be limited to the evaluation of those that are palatable and whose chemical composition is clearly balanced to at least cover the maintenance needs of rabbits (Villamide et *al*., 2010). For this reason, only a few raw materials can be distributed alone to the animals in order to obtain a direct measurement of their DE and DP content or apparent digestiblity of amino acids. For example, alfalfa hay, wheat bran, sunflower meal and Sorghum can be distributed to animals as a pure food, and their nutritional value can be determined directly (Villamide et *al*., 2010).

6-1-2- Substitution method

Not as the other monogastrics, in rabbits, the nutritional value of the majority of raw materials cannot be obtained via the direct method because of their nutrient imbalances compared to the rabbit's needs. In addition, when these materials are distributed as a single food, the time of digestive transit and ingestion can be changed by inducing a change in nutrient value (Fernandez-Carmona et *al*., 1996).Therefor, they must be incorporated into complet feeds with one or more rates; this is the substitution method (Maertens et *al*., 2002). This latter consists in replacing a certain amount of a basic diet with the food to be tested, and measur the digestibility of the basic diet and the experimental food (Maertens and Lebas, 1989). It is also possible to replace in the basic diet called reference whose digestibility is known by the raw material to be tested; it is the difference method. By the difference method, the digestibility of the raw material is calculated for energy (DE) and crude protein (DP). According to Villamide (1996), the digestible energy is obtained by the following formula:

$$DEt = (DEtd - (1-P)\ DEbd)/P$$

DEt: Digestible energy of raw material to be tested.

DEtd: Digestible energy of the food including the raw material to be tested at the proportion (**P)**

DEbd: Digestible energy of basal diet.

P: the rate of substitution of the raw material to be tested in the basal diet.

By using a substitution rate of 20 to 30%, specific energy values are obtained by difference for conventional raw materials for rabbit feeding (Villamide, 1996). This unique rate has some disadvantages, since there are raw materials that cannot be incorporated at rates above 20% for nutritional or technological reasons. For these reasons, the use of multiple substitution rates (4 and above) is recommended. It consists of the introduction of the raw material to be tested at several rates of incorporation into the basic diet (De Blas and Mateos, 2010). The evolution of the digestible energy according to the rate of incorporation is followed by a regression analysis. Through this latter, the value of the raw material studied corresponding to 100 % incorporation is then estimated. Thus, taking the DE of the basic diet as a reference, the energy value of the raw material can be determined by extrapolation to total substitution (De Blas and Mateos, 2010). However, to obtain convincing results, we must use the highest possible substitution rates. The period of adaptation of the animals to the experimental feed is at least 7 days (Villamide et *al*., 2010). The animals are fed ad libitum and the ingestion of each rabbit is measured during a period of 4 days, which represents the period of the test of the digestion according to the standardized European method of Perez et *al.* (1995). Feces are collected for each rabbit during these 4 days, and total feces collected are stored in the same individual bag at -18 ° C. During the collection of feces, it is necessary to avoid including the hairs lost by the rabbits, which can affect their protein content. For the calculation of digestibility, a sample of each food and feces collected are analyzed to determine their dry matter content (DM) and chemical composition. At the end, for each rabbit, an apparent digestibility value is calculated according to the following formula:

Apparent digestibility of DM (%) = ((DM ingested – DM excreted)/ DM ingested))*100

7- Carob composition and its use in animal nutrition:

The carob tree (*Ceratonia siliqua* L., *Fabacae Césalpinoïdae*) native to the eastern Mediterranean has been domesticated for 4000 years BC. It is an agro-sylvopastoral species with enormous socio-economic and ecological interests. The world production of carob pods is estimated at 310 000 tonnes mainly in Spain, Italy, Portugal, Morocco, Greece, Cyprus, Turkey and Algeria (Battle, 1997).

It is used for reforestation of areas affected by erosion and desertification, as an ornamental plant, to improve the standard of living of the rural population. Its pods, rich in sugar, are used in the agro-food industry as livestock feed, for the preparation of fruit juice and chocolate biscuit, as a substitute for cocoa; in therapeutics, especially as antidiarrheal; their high fiber content gives them hypocholesterolemic and hypoglycemic properties, it facilitates intestinal transit (Hariri et *al*., 2009). The important part in carob tree is its pods which are composed of two main parts: the pulp and the seeds (figure 07). Seeds are used predominantly in the food industry for locust bean gum, which contains approximately 90% galactomannans. Deseeded pods are also used in food industry (El Batal et *al*,. 2012 , 2013).

Figure 07: The carob bean pod (a) the pulp (b) and the seeds (c)

Carob, because of its high nutrient content (up to 95% of the carbohydrate) has been used for a long time for animal feed, either in its natural state or in the form of carob meal. Carob contains low content in protein (4 to 7.6 %) and fat content (0.2 – 2.3%), carob may be regarded as a healthy food source (Makris and Kefalas, 2008). Carob is caracterized by its high dietary fiber (up to 39.8% dietary fiber and 20% polyphenols) (Makris and Kefalas, 2008). The chemical composition of carob pods has been studied but the findings from the researchers from different locations differ. Such variations can be attributed to the fact that carob composition is strongly influenced by differences between cultivars and horticultural conditions (Ografakis et *al*,. 2000).

Experimental work

In Algeria, for many years, Professors from different universities in Algeria have carried out researchs as Berchiche's research team at Mouloud MAMMERI University in Tizi-Ouzou and Guemour, University Ibn khaldoun – Tiaret to contribute to the development of rabbit production specialy in its nutrition. The research of alternative raw materials to replace imported materials used in feed manufacturing for rabbits has been studied. The aim of that research is to make a productive, economic and healthy food for rabbits.

However, the rabbit as a monograstric herbivorous is very susceptible to digestive disorders. Previous work has shown that a change of food represents a disturbance that may be sufficient to cause digestive disorders to rabbits at weaning, which is accompanied by a strong food transition between a partially milk diet and an exclusively solid diet. So, to control this critical period it is necessary to control rabbits feeding.

This thesis is part of this research aimed at increasing the autonomy of the Algerian rabbit production. Its main objective is to contribute to the exploitation of one of by- products exist in Algeria, which is carob. This latter may be incorporated in rabbit's food.

The trials are oriented towards the exploration of alternative food sources for rabbits. The use of new sources in the granulated feed necessarily requires the determination of their nutritional value and to test if it is acceptable for the rabbit.

This thesis is presented in the form of publications, with the results of the trials carried out. It is structured in three parts:

- Evaluation of the use of carob pods (*Ceratonia silliqua* L.) in rabbit nutrition: effect on growth performances and health status after weaning;
- Evaluation of chemical composition of carob meal (*Ceratonia silliqua* L.) and its effect on growth performance in fattening rabbits;
- Effect of incorporation of carob meal (*Ceratonia siliqua* L.) on fecal digestibility and carcass yield in fattening rabbits.

In the first part, we have tested the acceptability of carob pods by rabbits and its effect on health status before testing its effect when it is incorporated in the food of rabbits as a complete and pelleted food in the second parts of this work.

I- Evaluation of the use of carob pods (*Ceratonia siliqua* L.) in rabbit nutrition: effect on growth performances and health status after weaning.

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1- Abstract:

The aim of this work was to study the utilization of carob pods by rabbits and its effect on growth performance, health status and economic efficiency in fattening period. In total 51 rabbits (local population - Algeria) weighing 481 ± 23.0 g weaned at 30 d of age were divided into three groups of 17 rabbits housed individually in flat-deck cages to record growth performances and health status. The first group "CM" received a commercial pelted food of fattening rabbits; the second group "CR" received only carob pods cracked while the third group "CRM" received both of commercial food and carob pods but each one in its own feeder. No antibiotic or medicines were used. Growth performances (feed intake, weight gain and feed conversion) are recorded at 30, 40 and 72 days of age while morbidity, mortality and health status are controlled usually. The results show that carob alone doesn't improve growth rate in rabbits because of a little consumption in comparison with the groups CM and CRM respectively (47.4 g/j, 99.6 g/j, 110 g/j. P=0.001) but improve feed intake when it is added to a commercial diet for the group CRM. However the daily weight gain hadn't been affected by the addition of carob to the diet between the groups CM and CRM between 40 and 72 d of age (P= 0.46) but it was different in the whole period (P= 0.036) . In other hand when carob is distributed with commercial feeds to rabbits there are no digestive problems as diarrhea in comparison with commercial feed or carob alone (P= 0.012) without any difference in mortality rates between groups (P= 0.25). As conclusion the addition of carob pods in rabbit's nutrition may improve growth performances by increasing the palatability of animals to feed and may avoid digestive problems specially diarrhea consequently decrease mortality but it must be incorporated to rabbits feed directly to justify its effect.

Key words: *Algeria, Alimentation, daily gain, diarrhea, diets, feed intake, mortality.*

1- Introduction:

In rabbit production, the period around weaning (28-35 d of age) is very critical. It is associated with a higher risk of digestive disorders (Lebas et *al* 1998; Gidenne and Garcia 2006).The most common disorder in rabbit production is the Epizootic Rabbit Enteropathy (ERE) which is the first cause of mortality in the European rabbit industry (Dewree et *al* 2003). This problem is accompanied by diarrheas, which caused to high mortality rates (30 to 80%) (Licois et *al* 1998; Marlier and Vindevogel 1998). The frequency of this problem is high during this period and the use of antibiotics is usual as standard treatment in many commercial farms. However, the wide use of antibiotics has led to the occurrence of antibiotic resistant bacteria (Falcao-Cunha et *al* 2007).Therefore the research of alternative solutions is indispensible. However, the rabbit is characterized by its ability to enhance the value of its food, it converts vegetable proteins into animal proteins (20%) and transforms the materials that are difficult to consume by humans into food that the latter readily accepts (Lebas 1975).Carob maybe one of this materials in Algeria. The carob pod is the fruit of the carob tree (*Ceratonia siliqua* L.) it is more used in the industry for the production of carob gum and locust bean gum, which are polysaccharides in the seed (Battle et *al* 1997). On the other hand, carob is considered as a high-energetic feed for animals because of its high level of sugars (48% - 56%) (Petit and Pinilla, 1995). In addition to its high carbohydrate content, carob is more palatable where it is shown that the inclusion of carob increases the palatability of animal diets (Cheeke 1987) and reduces the cost of feed for fattening lambs (Guessous et *al* 1989, Lanza et *al* 2001, Obeidat et *al* 2011). However, carob is largely utilized in animal feed against diarrhea for its high level in tannins (Würsch 1987) and also utilized to treat diarrhea in babies (Loeb et *al* 1989). It is in this perspective that our work is aimed at: the evaluation of growth performances (Ingested and weight gain) allowed by the carob; and the acceptability of carob by rabbits and its effect on health status.

2- Material and methods:

3-1- Location:

The experiment was carried out in the experimental farm of the University of IBN KHALDOUN –Tiaret from 30 December to 10 February, 2019.The farm is situated in the oust of the state characterized by a cold weather in winter and very hot in summer.

3-2- Diets:

Carob pods were obtained from the province of MEDEA in the west of Algeria. The carob was collected during the month of April 2018. After cleaning and treating the carob pods, they are cracked completely including seeds to be given to rabbits.

A commercial diet was obtained from the animal feed production unit of FAB GRAIN in TIARET. The ingredients and the chemical composition of both of carob pods and commercial diet are showed in table 10 and 11.

Table 10: Ingredient composition (%) of commercial diet

Ingredients	**%**
Alfalfa	20
Wheat	10
Soymeal 44	18.5
Wheat bran	12.4
Wheat straw	18
Barley	16.1
Soybean oil	2.5
Calcium carbonate	0.5
Dicalcium phosphate	0.5
NaCl	0.5
DL-Methionine	0.08
L-Lysine	0.2
L-Threonine	0.2
Corrector [1]	0.5

[1]*Provided by Group Bouhzila IMPEX (Setif, Algeria), (mg/kg): Mn: 4100; Zn: 11740; Cu: 2000; I: 250; CO: 99; Fe: 16000; Niacin: 4000; Betaine: 10830; Choline: 27500; Vitamin K: 200; Vitamin B1: 200; Vitamin B2: 400; Vitamin B6: 200; Vitamin A: 1700000 UI/Kg; Vitamin D3: 150000UI/Kg; Vitamin E(α-tocopherol acetate): 3800 UI/kg. 200 ppm de Clinacox 0.5% (Diclazuril).*

Table 11: Chemical composition (% DM) of the experimental diets

	CM	Carob pods
Dry matter	90.1	88.7
Starch	16.6	0.6
Crude protein	16.3	4.2
Ether extract	4.58	0.4
NDF	33.2	29.8
ADF	18.8	23.1
ADL	4.68	12.8
MM	5.74	2.76
Gross energy, Kcal /kg	2403	2147

3-3- Housing:

Before starting the experiment all the material and equipments were washed and disinfected with a commercial product for disinfection of farm's materials (TH5) and dried on sun. Rabbits used in the experiment were from local population mixed-sex. During the whole experimental period, both feed and water were administrated adlibitum and animals were kept in controlled environmental conditions as follows: temperature maintained at 25 ± 2ºC through heating and static ventilation system and a cycle of 12 h light: dark was established.

3-4- Growth performances and health status:

Fifty-one rabbits at 30 d-old with a body weight of 481 ± 23 g were blocked by litter and randomly assigned to the 3 experimental diets (17 rabbits per diet) and housed individually in flat-deck cages of 600 × 250 × 330 mm. The first group received the commercial diet "CM", the second group received the carob pods cracked "CR" while the third one received both of the commercial diet and the carob pods "CRM" but each one in its own feeder to record feed intake of each one of these later. Individual live weight and feed intake were recorded at 30, 40 and 72 d of age to evaluate growth performances between 30 to 40 d, 40 to 72 d and 30 to 72 d. The health status of rabbits (mortality and morbidity) was monitored daily from 30 to 72 d of age to evaluate the health risk. For diarrheas, we control animals every day in the morning and the evening (taking into account the appearance of the feces, fluidity and color according to a scale from 0 "normal feaces" until 5 "liquid". The prevalence of diarrheas is calculated by multiplying the severity score by the number of days with symptoms and dividing by the number of affected animals (Rozil lizard et *al* 2002).

3-5- Analytical methods:

Analyzes of commercial diet and carob pods had been done in the laboratory of animal production of the university. Methods of the AOAC (2000) were used to analyze DM (934.01), ash (967.05), CP (2001.11), starch (996.11) of the feed and carob pods. Ether extract was determined after acid-hydrolysis treatment (EC 1998). Dietary aNDFom (without sodium sulphite), and ADFom were sequentially determined using the filter bag system (Ankom Technology, New York) according to Mertens et *al* (2002) and AOAC procedure (2000, 973.187). The gross energy was measured with an adiabatic bomb calorimeter.

3-6- Statistical analysis:

The results obtained were analyzed as a completely randomized design in which the main sources of variation were the type of diets, using the General Linear Model (GLM) procedure of SAS (Statistical System Institute Inc., Cary, NC). The rabbit was used as the experimental unit in the analyses of growth performances and health status. For mortality we use analyze of variance considering rabbit alive with 0 and rabbit dead with 1 (Colin et *al* 2007).

4- Results:

4-1- Diets composition:

The commercial diet is formulated to meet the nutritive requirements for fattening rabbit according to De Blas and Mateos (2010) with 16.6 % of CP, 33.2 of NDF and 2403 kcal of gross energy. While the carob pods used in our experiment had low content in CP but a high level of NDF similar with those used by Boubaker et *al*. (2007).

4-2- Growth performances:

During the whole period of the experiment, we have seen that there is difference in performances between groups as it is shown in table 12. Rabbits fed carob pods alone showed the lower feed intake and growth rate in comparison with the other groups (P<0,001). However, the consumption of carob pods in the third group “CRM” was lower than the group received carob pods alone P<0,001. Nevertheless, animals fed commercial diet alone showed a high feed intake in comparison with the group “CRM” P<0,001. The addition of carob pods accompanied with the commercial diet in the third group “CRM” improve total feed intake of rabbits compared with the group “CM and CR” (6.1 kg *vs* 5.6 and 2.4 kg on average respectively P<0,001). The rabbits of the group “CRM” increase their daily weight gain in all the period of experiment while there is no difference in the final live weight of animals between the two groups (CM and CRM). Therefore, the carob pods alone showed the best feed conversion but the lowest weight at the final of the experiment.

Table 12: Effect of experimental diets on growth performances of rabbits between 30 and 72d of age.

	Expérimental diets[1]				
	CM	**CR**	**CRM**		***P-***
N[2]	12	13	14	**SEM**	***value***
Initial live weight, g	483	479	482	4.79	0.28
Final live weight, kg	2.24[a]	1.47[b]	2.27[a]	0.72	<0.001
Daily feed intake, g/d	99.6[b]	47.4[c]	110[a]	3.74	<0.001
Daily weight gain, g/d	41.1[b]	24.5[c]	42.2[a]	1.38	<0.001
Feed conversion, g/g	2.38[a]	2.02[b]	2.23[a]	0.26	<0.001
Feed distributed					
Commercial diet, Kg	5.6[a]	0	4.8[b]	3.17	<0.001
Carob pods, Kg	0	2.4[a]	1.3[b]	3.7	<0.001
Commercial diet + carob pods, Kg	0	0	6.1	.	.
Total feed distributed, Kg	5.6[b]	2.4[c]	6.1[a]	3.66	<0.001

*[1]**CM**: commercial diet. **CR**: Carob pods alone. **CRM**: commercial diet + carob pods*

*[2] **N**: number of animals finished the experiment.*

[abc] Means in the same row without common letter are different at P<0.05

4-3 Health status:

Health status is showed in table 13. Experimental diets did not affect mortality rates in the whole period of the experiment. In the period post weaning between 30 and 40 days of age we have contested difference between groups in morbidity where we found a high number of animals affected by diarrhea in the first group “CM” (9 rabbits) compared with the second group “CR” (3rabbits) and the third group “CRM” (2 rabbits) from a total of 17 rabbits per group *P*= 0.03. These results tended to increase the health risk in this experiment for the group “CM” and “CR” in comparison with group “CRM” *P*= 0.07.Even if the environment of rearing was not perfectly respected with the absence of antibiotics but the diarrheas which are observed are of type 1 and 2. The duration of these diarrheas is high in the period after weaning about of 7 to 10 days.

Table13: Effect of experimental diets on morbidity, mortality and diarheas in Rabbits between 30 and 72 d of age.

	Experimental diets[1]			
	CM	**CR**	**CRM**	
N	17	17	17	***P-value***
Morbidity				
from 30 to 40 days	9/17[a]	3/17[c]	2/17[b]	0.03
from 40 to 72 days	1/17	0	0	0.37
from 30 to 72 days	9/17	3/17	2/17	0.09
Mortality %				
from 30 to 40 days	23.5	23.5	17.6	0.89
from 40 to 72 days	5.88	0	0	0.37
from 30 to 72 days	29.4	23.5	17.6	0.25
Health risqué				
from 30 to 40 days	13/17	7/17	5/17	0.13
from 40 to 72 days	2/10	0	0	0.37
from 30 to 72 days	14/17	7/17	5/17	0.08
Presence of diarhea from 30 to72 days %	0.52[a]	0.17[b]	0.11[c]	0.01

[abc] *Means in the same row without common letter are different at P<0.05*

5- Discussion:

The target of this work was to evaluate the effect of the use of carob pods in rabbit's nutrition in fattening period. The use of carob pods alone by the rabbits in all the fattening period don't improve growth performances and reduced the growth rate because of the nutritive value of this later and the little quantity of feed intake in comparison with the commercial diet (P<0,001) according with the results obtained by Guemour (2010). The carob pods had a high level in tannins which are polysaccharides may reduce palatability and feed intake of animals as it is found in poultry (Bullard et Elias 1980). Other results about the use of carob in poultry show that tanins reduce the growth performances (Vohra et Kratzer 1964).However, in addition to their low level on protien content carob pod contain tannins that can act as antinutritional factors, and may reduce the digestibility of proteins in rabbits rations to lead to a lowly growth in acordance with studies in pigs by (Mariscal-Landin et *al* 2004).

Animals received only carob pods showed high feed intake of this later than the third group because animals in the third group have another feed which is the commercial diet , this result justify that rabbits accept carob as feed not only granulate feed. The addition of carob pods accompanied with the commercial diet in the third group “CRM” improve total feed intake of rabbits in all the experiment, maybe this is related with the effect that carob is rich in total sugars 48% - 56% (Petit and Pinilla 1995) which increase palatability of animals to feed.Teillet et *al* (2011) didn’t found any effect of the use of carob seed extract on the feed intake of rabbits in fattening period.However, the supplementation of the pigs feed with 6% of carob flower improve feed intake (+62 g/d) and growth rate (+40g/d) in comparison with control diets (lizardo R et *al* 2002). According with pevious studies by Kotrotsios et *al* (2012) it is shown that the incorporation of carob at 75 g/kg and 100 g/kg increase body weight of pigs. At final, we have found an increase in growth rate by rabbits received both of carob pods and commercial diet. Feed coversion was different between groups in contrast Kotrotsios et *al* (2012) did not found any difference in pigs.

The addition of carob pods accompanied with commercial diet for rabbits reduced mortality in weaning period in accordance with Teillet et *al* (2011) where he found a reduction in mortality rate when rabbits received carob seed extract. The most raison of mortality in rabbit’s farms is diarrheas and in our experiment we found a reduction of this later when we add carob pods to rabbits diets. Consequently, this situation helps to increase viability of animals at weaning. This effect may be explained by the level of mannanes (24.6% in carob seeds) (Dakia et *al* 2008) which have a beneficial effect on animal health as it is shown in piglets (Van Nevel et *al* 2005). Therefore, carob is rich in antioxidants to explain the favorable effect on animal health (Custodio et *al* 2011). Carob utilization in the experiment affect the prevalence of diarrheas in rabbits so it was found that carob is used to prevent diarrheas for its high level in tannins (Würsch 1987) and also utilized in babies against this problem (Loeb et *al* 1989).

6- Conclusion:

In conclusion, from the present study it is evident that the use of carob pods is favorable and accepted by rabbits and it has a positive effect on rabbit’s health around weaning to prevent diarrheas and improve feed intake because of its high palatability. The low number of animals used in the experiment and the absence of repetitions can’t justify these results but it showed that rabbits accept carob as food. Moreover, the way of using carob in the experiment as cracked is difficult to be controlled so the incorporation of carob in the pelleted feed of rabbits at different levels in futures experiments using a high number of animals may be the best way to test this later. Consequently, carob pods could be suggested as a potential feed for fattening rabbits.

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II- Evaluation of chemical composition of carob meal (*Ceratonia siliqua* L.) and its effect on growth performance in fattening rabbits.

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1- Abstract:

The aim of this work was to study the proximate composition of carob meal in Algeria and its effect of on growth performances in fattening rabbits. Carob pods were collected on April 2018 from the west region of Algeria to be used in the experiment. Four experimental diets were prepared. A control diet "C" was formulated to meet the nutritive requirements for fattening rabbit. Another three diets "CR05, CR10 and CR15" were obtained by replacing 5, 10 and 15 % of barley in the control diet respectively by carob meal. In total 92 rabbits (23/ treatment) weighing 540 ± 32 g weaned at 35 d of age were used to record growth performances at 35 and 77 days of age. The analysis shows that our carob has a low content in CP (4,2 %) but a high content in fiber (20,7%). The inclusion of carob at 10 and 15% increased feed intake of animals (P= 0.002) without any effect on weight gain (P= 0.98) and feed conversion (P= 0.66). As conclusion carob may be used in rabbit's diet and its incorporation increase palatability of animals.

Key words: *Algeria, Alimentation, daily gain, feed intake, mortality.*

2- Introduction:

In rabbit, breeding the largest share (70%) of production costs is represented by food (Maertens and Gidenne 2016, Gidenne et *al* 2017). While in Algeria, the majority of raw materials used in food formulation are based on corn and soybean meal, which are imported from abroad and in direct competition with human food. This has resulted un increase of 25-30% in rabbit food's price. This situation obliged the food producers to increase the price of food (Duperray 2008). In this case, the research for alternative sources or agro-industrial co-products available locally is an interesting approach in such a situation. Carob can take a part in the solution of this problem by its high availability in Algeria with a low price. In previous studies, carob gives positive results on growth performances in fattening lambs at a level of 30 % (Guessous et *al* 1989, Lanza et *al* 2001, Obeidat et *al* 2011). A study shows that the incorporation of carob into the rabbit diet shows good fermentation at the caecum because of its large content of soluble fiber (Gasmi-Boubaker et *al* 2013) and has a positive effect on health status after weaning (Guenaoui et *al* 2019). It is in this context that our work is aimed at: The determination of carob composition in Algeria and its effect on growth performances (Ingested and weight gain) in fattening rabbits

3- Material and methods:

Carob pods were obtained from the province of MEDEA in the west of Algeria. The carob was collected during April 2018. After cleaning and treating carob pods, they were milled into fine particles of 1 mm including seeds to be included in the experimental diets. These later were made in the animal feed production unit of FAB GRAIN in TIARET. The diets were presented as pellets of 3.5 mm/ 15 mm. A control diet "C" was formulated to meet the nutritive requirements for fattening rabbit according to De Blas and Mateos (2010). Three more diets CR05, CR10 and CR15 were obtained by replacing 5, 10 and 15 % of barley by carob meal from the control diet so they have the same nutritive value around (16% of CP and 2400 Kcal of gross energy).

3-1- Growth performances and health status:

Ninety-two rabbits at 35 d-old with a body weight of 540 ± 32 g were blocked by litter and randomly assigned to the 4 experimental diets (23 rabbits per diet) and housed individually in flat-deck cages of 600 × 250 × 330 mm. Individual live weight and feed intake were recorded at 35 and 77 d of age. The health status of rabbits (mortality and morbidity) was monitored daily from 35 to 77 d of age.

3-2- Analytical methods:

The methods of the AOAC (2000) were used to analyze DM (934.01), ash (967.05), CP (2001.11). Dietary aNDFom (without sodium sulphite), and ADFom were sequentially determined using the filter bag system (Ankom Technology, New York) according to Mertens et *al* (2002) and AOAC procedure (2000, 973.187). The gross energy was measured with an adiabatic bomb calorimeter.

3-3- Statistical analysis:

The results obtained were analyzed, using the General Linear Model (GLM) procedure of SAS (Statistical System Institute Inc., Cary, NC). The rabbit was used as the experimental unit and the type of diet as the main sources of variation.

4- Results and discussion:

4-1- Carob composition:

Table 14: Proximate composition of carob meal (% DM basis)

	References		
	(1)	**(2)**	**(3)**
Dry matter	88.7	88.8	94
Crude protein	4.2	4.68	4.63
Crude fiber	20.7	21	-
NDF	29.8	31.2	29.15
ADF	23.1	26.2	26.05

***(1)**: Carob used in our study, **(2)** : (Gasmi-Boubaker et al 2008), **(3)** : (William et al 2005)*

In our study, the chemical composition of carob used was generally similar with those previously reported. Overall, carob is poor in crude protein as it is found in our study and in agreement with the results of Gasmi-boubaker et *al* (2008) and Williams et *al* (2005) because they are from the same region (the Mediterranean).While, Thomson (1971) found percentage ranges of (2.2 – 6.6 %) for crude proteins and (4.2 – 9.6 %) for crude fiber.

4-2- Growth performances and health conditions:

Table 15: Effect of experimental diets on growth performances and mortality of rabbits between 35 and 77d of age.

	Experimental diets[1]					
	C	**CR5**	**CR10**	**CR15**	**SEM**	***p value***
N[2]	20	22	22	23		
Live weight 35 d, g	539	539	541	540	32.9	0.99
Live weight 77 d, g	2064	2053	2089	2096	137	0.72
Feed intake, g/d	101[b]	101[b]	104[a]	104[a]	3.21	0.002
Weight gain, g/d	36.3	36.1	36.2	36.3	3.02	0.98
Feed conversion, g/g	2.81	2.85	2.9	2.87	0.23	0.66
Mortality %	13.04	4.34	4.34	0	.	0.26

*[1] **C**: control diet. **CR5** : incorporation of 5% of carob. **CR10** : incorporation of 10% of carob,*
***CR15 :** incorporation of 15% of carob [2]**N**: number of animals finished the experiment.*
***abc** Means in the same row without common letter are different at P<0.05*

Dietary incorporation with 10 and 15 % of carob improved feed intake of animals in comparison with the control and the CR5 diets without any effect on the daily weight gain and feed conversion in accordance with results found by Guenaoui et *al* (2019). This enhancement in feed intake maybe due to the high content of carob in total sugar, which increases palatability of animals. In contrast, the addition of carob meal reduced palatability in poultry breeding (Bullard et Elias 1980). However, there was not any effect of diets on mortality rate.

5- Conclusion:

Carob has a low content of CP but high content of fiber and may replace barley in rabbit's diets but it is necessary determine the total carbohydrates in carob to benefit more from this matter. However, the inclusion of carob has a positive effect on feed intake and may be used to increase palatability of diets in rabbits.

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III- Effect of incorporation of carob meal (*Ceratonia siliqua* L.) on feacal digestibility, slaughter performances and carcass yield in fattening rabbits.

In preparation

1- Abstract:

The aim of this work was to study the effect of the incorporation of carob on apparent digestibility and carcass yield in fattening rabbits. Four experimental diets were prepared. A control diet “C” was formulated to meet the nutritive requirements for fattening rabbit. Another three diets “CR05, CR10 and CR15” were obtained by replacing 5, 10 and 15 % of barley in the control diet respectively by carob meal. No antibiotic or medicines were used. Faecal digestibility was measured from 42 to 45 d of age (6 rabbits / diet). At the end of the experiment (77 d of age), 10 rabbits from each group were slaughtered to determine slaughter performances and carcass yield.

The results show that carob incorporation has a positive effect on dry matter (P= 0.004) and organic matter (P= 0.0008) digestibility of rabbits, in contrast it was observed that the digestibility of fat and proteins were decreased in rabbits fed diets contains 10 and 15% of carob meal. For slaughter performances, there was no effect of carob instead for the fat rate, which was decreased in rabbits fed the CR15 diet. As conclusion carob meal incorporation in rabbits diets may improve digestibility of diets less digestible but it must be determined the optimum level of incorporation in the pelleted food of rabbits to avoid negative effects.

Key words: *Algeria, Alimentation, slaughter, Dry matter, digestibility.*

2- Introduction:

In Algeria, the increase in meat demand leads to look for other ways than cattle and sheep to increase meat production. Against this situation, other strategies are needed, namely the promotion of poultry and rabbit. This latter can partially reduce the deficit in animal protein. However, the development of rabbit production in Algeria can be justified because it is a species known and adapted to the environment for a long time. In addition, rabbit breeding is favored by its biological and zootechnical potential. It is a species known for its high productivity, more than 45 rabbits or 61 kg of meat per female per year (Koehl 1994). Indeed, these strategies have not achieved the objectives set because of the foreign dependence on factors of production, especially biological material and food.

In rabbit breeding, the largest share (70%) of production costs is represented by food (Maertens and Gidenne 2016, Gidenne et *al* 2017). While in Algeria, the majority of raw materials used in food formulation are based on corn and soybean meal, which are imported from abroad and in direct competition with human food. This has resulted an increase of 25-30% in rabbit food's price. This situation obliged the food producers to increase the price of food (Duperray 2008). In this case, the research for alternative sources or agro-industrial co-products available locally is an interesting approach in such a situation. Carob can take a part in the solution of this problem by its high availability in Algeria with a low price.

In previous studies, there are different results about the use of carob and its level of incorporation in animal diets. Carob gives positive results on growth performances in fattening lambs at a level of 30 % (Guessous et *al* 1989, Lanza et *al* 2001, Obeidat et *al* 2011). Performances of growing calves were also improved by replacing barley with carob pulp at a dietary level of 30% (Louca and Papas 1973). While, Ouchkif (1988) recorded the best performances in growing lambs by the inclusion of 20% of carob in diet. However, Bugarski et *al* (1971) suggested that the incorporation of carob pulp should not exceed 10 % of the diet. Therefor, carob could be used in rabbit feeding.

Indeed, there are few studies in this area. A study shows that the incorporation of carob into the rabbit's diet shows good fermentation at the caecum because of its large content of soluble fiber (Gasmi-Boubaker et *al* 2013) and has a positive effect on health status and feed intake after weaning (Guenaoui et *al* 2019). In other hand carob incorporation improved digestibility of rabbits diets (Gasmi-Boubaker et *al* 2008) .However, there are no specific studies on the optimal level of its inclusion in a practical diet. It is in this context that our work is aimed at:

- The effect of carob meal incorporation on feacal digestibility at different levels in rabbit's diets;
- Its effect on carcass yield and slaughter performances of fattening rabbits.

3- Material and methods:

3-1- Location:

The experiment was carried out in the experimental farm of the University of IBN KHALDOUN – Tiaret in Algeria from 05 March to 17 April 2019.

3-2- Diets:

Carob pods were obtained from the province of MEDEA in the west of Algeria. The carob was collected during the month of April 2018. After cleaning and treating the carob pods, they were milled into small particles of 1 mm to be included in the experimental diets. These later were made in the animal feed production unit of FAB GRAIN in TIARET. The diets were presented as pellets of 3.5 mm/ 15 mm.

A control diet “C” was formulated to meet the nutritive requirements for fattening rabbit according to De Blas and Mateos (2010). Three more diets CR05, CR10 and CR15 were obtained by replacing 5, 10 and 15 % successfully of barley by carob meal from the control diet. The four experimental diets were formulated so they have the same level of CP and gross energy. The ingredients and chemical composition of experimental diets are showed in the table 16. No antibiotics neither medicines were supplemented to the diets during the experiment.

Table 16: Ingredients and chemical composition of experimental diets (%).

	C	CR5	CR10	CR15
Barley	21	16	11	6
Wheat	4.5	4.5	4.5	4.5
Soymeal	18.5	18.5	18.5	18.5
Soybean oil	2.5	2.5	2.5	2.5
Calcium carbonate	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.5	0.5	0.5	0.5
wheat straw	14	14	14	14
Wheat bran	12.8	12.8	12.8	12.8
Carob meal	**0**	**5**	**10**	**15**
Alfalfa	25	25	25	25
L-Lysine HCL - 98%	0.05	0.05	0.05	0.05
DL- Methionine	0.05	0.05	0.05	0.05
L- Threonine	0.1	0.1	0.1	0.1
Corrector[1]	0.5	0.5	0.5	0.5
chemical composition				
Dry matter	89.1	89	88.8	88.7
Crude protein	16.9	16.8	16.5	16.2
Ether Extract	4.71	4.65	4.57	4.49
Crude fiber	15.5	16.4	17.2	17.8
NDF	32.8	33.4	33.9	34.4
ADF	19.1	20.1	20.9	21.8
ADL	3.74	4.35	4.96	5.5
MM	5.74	5.78	6.02	5.9
Starch	15.9	13.9	11.4	8.88
Gross energie, Kcal/Kg	2456	2441	2397	2353

[1] Provided by Group Bouhzila IMPEX (Setif, Algeria), (mg/kg): Mn: 4100; Zn: 11740; Cu: 2000; I: 250; CO: 99; Fe: 16000; Niacin: 4000; Betaine: 10830; Choline: 27500; Vitamin K: 200; Vitamin B1: 200; Vitamin B2: 400; Vitamin B6: 200; Vitamin A: 1700000 UI/Kg; Vitamin D3: 150000UI/Kg; Vitamin E (α-tocopherol

3-3- Housing :

Before starting the experiment all the material and equipments were washed and disinfected with a commercial product for disinfection of farm’s materials (TH5) and dried on sun. Rabbits used in the experiment were from local population mixed-sex. During the whole experimental period, both feed and water were administrated adlibitum and animals were kept in controlled environmental conditions as follows: temperature maintained at 21 ± 2ºC through heating and ventilation system and a cycle of 12 h light: dark was established.

3-3- Faecal digestibility:

The faecal digestibility of the experimental diets was measured on 24 rabbits among those on trial, with an initial body weight of 549 ± 48 g (6 rabbits per diet) and housed in metabolism cages measuring 400 × 510 × 330 mm from 42 to 45 d of age according to the European standardized method (Perez et *al* 1995). After 7 d of adaptation, feces were collected daily for three consecutive days (42 to 45 d of age) from each cage and the feed intake was recorded. Faecal samples were stored at −20 °C for analyses. Samples of the feeds offered to the animals were collected at the end of the faecal collection period to be analyzed.

3-4- Slaughter performances:

During two consecutive days (at 77 and 78 d of age), 40 rabbits (10 per treatment) were slaughtered between 9:00 and 12:00 h without fasting before. The measurements of various body fractions, including abdominal viscera, were recorded according to the methodology previously described by (Lebas et Laplace 1982). The body weight and the weight of: total digestive tract, skin, kidneys, liver and hot carcasses were recorded immediately using an electric balance (Annex). In order to evaluate carcass yield, the following criteria were measured according to World Rabbit Science Association standards (Blasco and Ouhayoun, 1996): cold carcass weight (commercial carcass), fat and thighs weight.

The formulas applied for the calculation of the performances of carcass yield are as follows:

- Commercial carcass yield (%) = (commercial carcass weight / live weight before slaughter) x 100.
- Hot carcass yield (%) = (hot carcass weight / live weight befor slaughter) x 100.
- Thigh yield (%) = (thigh weight / commercial carcass weight) x 100.
- Fat (%) = (fat weight / commercial carcass weight) x 100.

3-5- Analytical methods:

The analyses were done in the laboratory of animal production - Faculty of natural sciences and life of the university. For the chemical analysis of both of carob pods and the four experimental diets, the methods of the AOAC (2000) were used to analyze DM (934.01), ash (967.05), CP (2001.11). Dietary aNDFom (without sodium sulphite), and ADFom were sequentially determined using the filter bag system (Ankom Technology, New York) according to Mertens et *al* (2002) and AOAC procedure (2000, 973.187). The gross energy was measured with an adiabatic bomb calorimeter.

3-6- Statistical analysis:

The results obtained were analyzed as a completely randomized design in which the main sources of variation were the type of diets, using the General Linear Model (GLM) procedure of SAS (Statistical System Institute Inc., Cary, NC). The rabbit was used as the experimental unit in the analyses apparent digestibility, slaughter performances and carcasse yield.

4- Results:

4-1- Faecal digestibility :

The apparent digestibility of different nutrients is shown in table 17. The incorporation of carob did not affect the digestibility of gross energy and crude fiber, while the feacal digestibility of dry matter, organic matter and ether extract were different between groups. Rabbits fed the CR15 diet increased their feacal digestibility of dry matter in comparison with the CR5, CR10 and the control diet (P=0.004). Also, the dry matter digestibility of CR10 diet was better than the controle diet, while there was no difference between CR10 and CR5 neither between CR5 and control diets. Carob incorporation in the diets CR5, CR10 and CR15 increase the organic matter digestibility compared to the control diet (P= 0.0008). In contrast the digestibility of ether extract was better for the control and CR5 diets than the other two diets (CR10 and CR15) with un P= 0.0016. Morever rabbits fed diets containes carob (CR5, CR10 and CR15) tended to decrease their fecal digestibility of protiens compared to the control diet (P= 0.08).

Table 17: Effect of experimental diets on the apparent faecal digestibility of 42 d old rabbits

	Experimental diets[1]					
	C	CR5	CR10	CR15	SEM	*P-value*
N[2]	6	6	6	6		
<u>**Aparent faecal digestibility (42-45d)**</u>						
Feed intake g/d	78.6	79.1	79	78.7	1.49	0.92
Dry matter	59.4^{c}	60.2^{bc}	60.7^{b}	61.8^{a}	1.09	0.004
Organic matter	61.1^{b}	63^{a}	63.5^{a}	64.2^{a}	1.2	0.0008
Gross energy	63.7	64.1	64.6	65.3	1.64	0.37
Crud protein	71.6	70.72	70.39	70.02	1.06	0.08
Crude Fiber	27.4	29.6	28.9	29.5	3.58	0.68
Ether extract	73.8^{a}	73.2^{a}	69.5^{b}	69.7^{b}	2.08	0.0016

[1] **C**: control diet. **CR5** : incorporation of 5% of carob. **CR10** : incorporation of 10% of carob, **CR15** : incorporation of 15% of carob [2]**N**: number of animals finished the experiment.
abc Means in the same row without common letter are different at P<0.05

4-2- Carcass yield

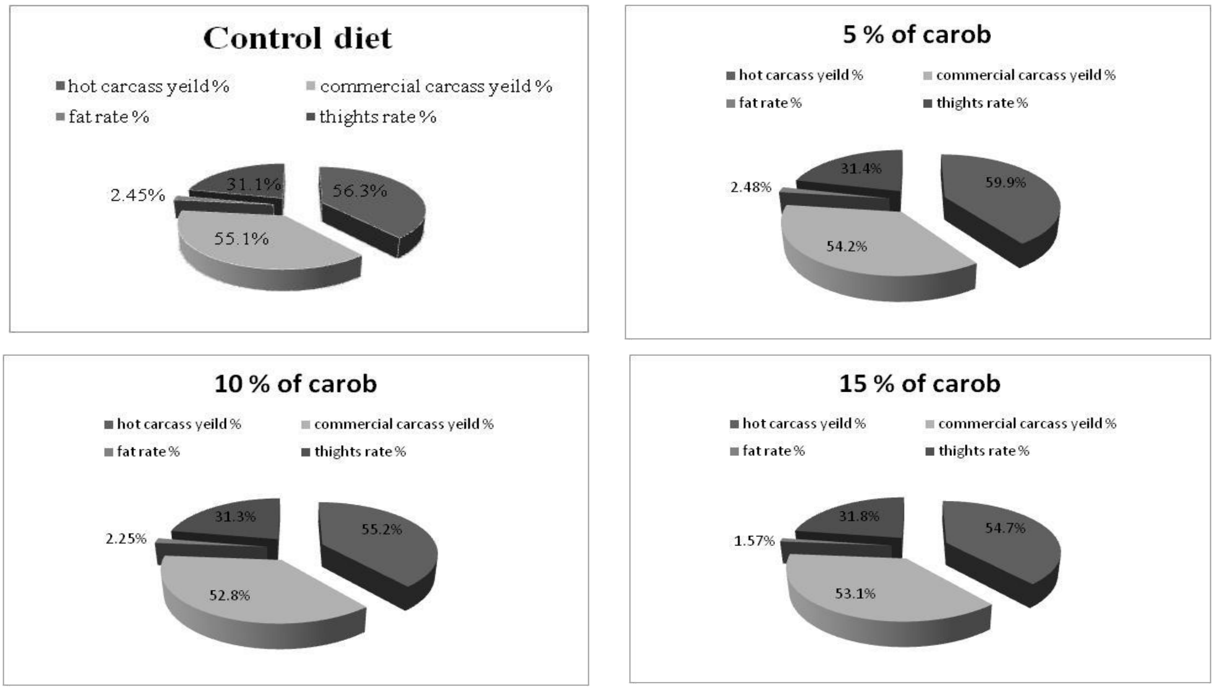

Figure 08: Effect of diets on carcass yield in rabbits

For carcass yield as it is shown in fugure 1, there were no differences between groups instead for fat rate which was higher for C and CR5 diets than CR15 one but for the CR10 diet still without any difference between groups (P= 0.05).

4-3- Slaughter performances :

Slaughter performances and carcass weight are shown in table 18. Incorporation of carob at different levels did not affect the weight of skin, total digestive tract, liver, kedneys and thighs in rabbits after slaughtering. Instead of the weight of fat where we found a tendence for the control and CR5 diet to be increased in contenent of fat compared with CR15 diet, while we didn't find any differenc between CR10 and other diets (P= 0.08).

Table 18: Effect of experimental diets on slaughter performances of rabbits at 77d of age.

	Experimental diets[1]					
	C	**CR5**	**CR10**	**CR15**	**SEM**	***p value***
N[2]	10	10	10	10		
weight in (g) of						
Body weight	2019	2072	2140	2127	124	0.13
Skin	281	285	287	290	13.9	0.58
Digestive tract	349	354	352	363	32.6	0.77
Liver	70.6	79.4	80.2	81.2	12.2	0.21
Kidneys	17.2	17.9	17.6	17.8	2.12	0.88
Fat	27.1	27.8	25.4	23.7	3.74	0.08
Thighs	344	350	351	356	32.62	0.88
Hot carcass	1136	1177	1180	1165	63.5	0.41
Commercial carcass	1108	1119	1122	1124	60.9	0.93

[1] **C**: control diet. **CR5** : incorporation of 5% of carob. **CR10** : incorporation of 10% of carob, **CR15** : incorporation of 15% of carob [2]**N**: number of animals finished the experiment.

5- Discussion:

The incorporation of carob in rabbits diets improve DM and OM digestibility according with results found by Gasmi-boubaker et *al* 2008. These results could be justified by the high content of carob on non-nitrogen cellular components, which are rapidly degraded by gut microorganisms. Carob incorporation in the diet has a negative effect on protein and fat's digestibility, the values showing a similar decreasing in this latter so that observed by

Vohra and Kratzer (1964) using carob gum and carob seeds in poultry (Ortiz et *al* 2004). The low digestibility of proteins may be explained by the fact that carob is rich in tannins which inhibit digestive enzymes leading to high depression in proteins digestibility. Nevertheless, crude fiber digestibility was low without any difference between diets in concordance with results of Gidenne (1990).

For slaughter performances, all rabbits from different groups had passed the 2kg at 77J of age, which is the preferred weight in the Algerian market (Kadi et *al* 2008). Over all, slaughter parametres were not affected by diets acording with results found in lambs by Lanza et *al* (2001). Carcass yield was not affected by the dietary inclusion of carob at any level, compared to control, while carcass yield value (53.8% in average) was a littel bit lower than that aported by Guemour et *al* (2010 ; 57,9%) and Kadi et *al* (2011; 59,2%) but at 84j of age. The main difference between groups was observed in fat rate, in contrast, there was no difference in carcass fatness in lambs receiving dits containes 10% of carob (Lanza et *al* 2001).

6- Conclusions:

- Results show that carob increase digestibility of dry matter and organic matter but have a negative effect on proteins and fat digestibly;
- In the present study the most constraint in using carob is its high content in tannins which were not determined in this experiment, so the quantification of this latter in future studies is indispensable to justify the effect of carob in rabbit’s nutrition;
- Indeed, the experiment needs repetitions to determine the optimum level of carob that must be used to improve growth performances and digestibility in rabbits. Nevertheless, the association of carob with other ingredients low acceptable by rabbits is indispensable to justify its effect on palatability.

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GENERAL DISCUSSION

General discussion:

The objective of our work was the study of one of the most abundant by-products used in animal nutrition in Algeria to see if it may be one of alternative food sources in rabbit nutrition. On the other hand, preserving and managing animal health is one of the major issues in the animal production sector in general and in the rabbit farms in particular. This issue, reinforced by the Ecoantibio 2017 plan (https://agriculture.gouv.fr/ecoantibio-2017), requires reducing the use of antibiotics and has forced the sector to search for alternatives to antibiotic therapy. There are several levers of action to reduce the use of antibiotics (Falcao-Cunha et *al*., 2007). A diet well adapted to the physiological stage of the animal may be one of the solutions to this problem.

However, Carob has a benefic effect as anti diarrhea food in humans and animals because of its high content in tannins and sugar. In rabbits, the major problem in the period around weaning is the digestive disorder accompanied with diarrhea. So, the use of carob may limit or reduce the incidence of this problem. To test the effect of this ingredient in rabbit production we have done two experiments on local population rabbits after weaning until the final fattening period:

The first experiment consists on the test if carob is accepted by rabbits or not, to be incorporated at different levels in the second experiment to see the effect on growth performances, apparent digestibility, slaughter parameters and carcass yield. The trials were carried out in the experimental farm of the University of Ibn Khaldoun – Tiaret with controlled environmental conditions. The carob pods and the experimental diets were prepared in the animal food production unit of “FAB GRAIN” in Tiaret. In total, we have used 143 weaned rabbits from local population in this study. Analyzes of DM and OM of raw materials, experimental diets and feces were done in the laboratory of the university while the other were done abroad.

Carob is very rich in total sugars (Leroy, 1929, Avallone et *al*., 1997) contributing to increase the palatability of the diets of animals. In addition, the pulp of carob also has very high fiber content (27-50%) and a significant amount of tannin (Saura-calixto, 1988). This latter has important anti-diarrheal properties (Würsch, 1987). As it is known in other studies that tannins have an antinutritional effect that’s why we chose to test if carob is accepted by rabbits or not in the first experiment and to see its effect on health status. Results show that rabbits accept carob alone but doesen't improves growth performances. While its distrubution acompanied with pelleted food for rabbits increase the total feed intake. This result justify the effect of carob in increasing palatability of diets, so this point is very important in rabbit nutrition where we have problems in diets less accepted. In other hand, in rabbits fed carob we did not have digestive problems or diarrhea leading to low rate of mortality and this may help in improving health status of animals without using antibiotics.

In the second experiment where carob is incorporated at 5, 10 and 15 % in rabbits diets, we did not see any effect on growth rate or feed conversion. Wherever, the diets containes 10 and 15% improved feed intake of rabbits. These results justify the effect of the palatability of carob in diets. In the whole period, the health status of animals was good and we did not see any symptomas of diarrhea in rabbits fed diets containes carob. This results shows that carob has not any effect on grawth performances in rabbits but it may help in increasing palatability of diets and improving health status of rabbits after weaning.

From the objectives of this work is the research of other raw materials or alternatives used in the formulation of rabbit's food to decrease a little bit from the importation of raw materials, which are very expensive. In this simple work, we try to do an economic study to see the benefit and the advantage of the use of carob in rabbit's diet. The study consists on the determination of the cost of diets using carob in comparison with commercial diets used in Algeria. At the final of the first experiment all animals were sold to butchery and the carcass weight was recorded to evaluate economic performances. Economic efficiency was calculated from the equation of Asar et *al* (2010):

- Economic efficiency (%) = [(income in weight gain (DA / kg) - Total feeding cost in DA / kg) / Total feeding cost in DA / kg] X 100
- Economic Efficiency % = Net income / Cost of Food.
- Income in weight gain = total weight gain (kg) * price of one kg of live body weight.
- Total feeding cost = total ingested food (kg / rabbit) * price of one kg of food.

The results of economic efficiency are shown in table:

Table 19: Economic performances of the experimental groups.

	Experimental diets						
			CRM				
	CM	**CR**	**CR**	**CM**	**CRM**	**SEM**	***P-value***
N	9	13		14			
live weight at 30 d (Kg)	0.48	0.48		0.48		0.004	0.26
live weight at 72 d (Kg)	2.23^{a}	1.47^{b}		2.28^{a}		0.06	<0.001
total weight gain (kg)	1.75^{a}	0.99^{b}		1.8^{a}		0.06	<0.001
price DA/ Kg live weight	450	450		450			
Income in weight gain DA/kg	787.68^{a}	446.38^{b}		812^{a}		27.1	<0.001
Total feed intake / rabbit (kg)	4.4^{b}	2.13^{c}	1.03	3.88	4.91^{a}	0.19	<0.001
Price of 1 Kg of food, DA	47	15	15	47	.	.	.
Total coste of food / rabbit, DA/kg	206.9^{a}	31.98^{b}	15.45	182.36	198.18^{a}	9.24	<0.001
Carcass weight Kg	1.18	0.78		1.23		.	.
price of 1 Kg of meat	900	900		900		.	.
Total sold meat (Kg)	10.62	10.14		17.22		.	
Total cost of meat solded (DA)	9558	9126		15498		.	.
Economic efficiency %	281.67^{c}	1302.43^{a}		311.06^{b}		90.5	<0.001

DA: *Algerian dinar*, **Kg***: Kilogram* [1]***CM****: commercial diet.* ***CR****:Carob pods alone.* ***CRM****: commercial diet + carob pods.*[2] ***N*** *: number of animals finished the experiment.*

[abc] Means in the same row without common letter are different at P<0.05

In this experiment we found that the best feed economic efficiency is obtained in the group fed by carob pods alone but this group gives the lowest quantity of sold meat at slaughtering because of the lowest body weight and number of animals alive. The carob pods are very cheap in comparison with commercial diet (15 DA/Kg vs. 47 DA/Kg) so it may reduce the cost of diet as it was found in fattening lamb's feed (Guessous et *al* 1989, Lanza et *al* 2001, Obeidat et *al* 2011). In contrast carob did not reduce the cost of diet when it was accompanied to commercial diet because of the high quantity of this later ingested by rabbits. This is related to the way of using the carob pods because they should be incorporated and pelleted directly to the rabbit's feed and not be used alone. Although carob did not reduce the cost of feed and did not improve performances of rabbits but it helps to prevent diarrheas at weaning and improve rabbit's health to owing to high viability rate at the final of fattening period.

Critical analysis of our experimental strategies and methodological choices:

Our work presents several originalities. We sought to have a global vision on the use of carob in the rabbit diet by studying growth performances and digestibility during the growth and fattening phase. On the other hand, we study the effect of this latter on the health status of weaning rabbits and its economic benefit in the food production. The unavailability of different raw materials used in fabrication of animals food take an obstacle in the formulation of experimental diets, That’s why we choose to replace partially barley with carob to obtain diets which are nearly similar in nutritive values. The limit number of animals per group, the non-repetitions of experiments can’t justify the results. The use of local population rabbits, where the number of rabbits per litter is very low (4 to 6 per litter) can’t allow us to do a veritable experimental design. Furthermore, the unavailability of laboratory materials and analysis has prevented us to do supplemented studies to justify the effect of carob in rabbit’s diets as the determination of the fermentation activity and the effect of this ingredient on the microbiota of the digestive tract of rabbits.

Conclusion and perspectives

Conclusion and perspectives:

The results obtained during this thesis work made it possible to improve our knowledge on carob as alternative sources in rabbit nutrition and to confirme that it is possible to introduce this product in the fabrication of rabbit's food.

Indeed, our results show that the introduction of carob in rabbit's food improves feed intake because of its high palatability. However, carob could be considered as a good source of energy, and fiber for growing rabbits. Carob remains comparable to some ingredients used in animal nutrition such as barley for example. Therefore, it deserves to be explored more precisely in this domaine. However, carob increase digestibility of dry matter and organic matter but have a negative effect on proteins and fat digestibly without any effect on growth performances.

The mortality rate of rabbits was very low in all of our work. Therefore, it remains difficult to establish on the basis of our results alone, a direct link between the use of carob and the health staus of animals, but we had confirmed the effect of carob in providing the problem of diarrheas in the period around weaning.

We have also determined that the use of carob separated or incorporated in rabbit's diets can have an economic interest in rabbits breeding because of its low price in the marcket.

This work allows us to envisage real perspectives. We can put forward some areas of development for the carob use in the formulation of granulated foods: more detailed studies can be conducted with a view to:

- Determine the optimum rates of incorporation of this alternative source in rabbit's diets;
- The quantification of tannins in future studies is indispensable to justify the effect of carob in rabbit's nutrition;
- Determine the effect of carob on the gut health, the digestive microbiota and ceacal fermentation to exploit more the use of this latter in rabbit nutrition;
- Carry out technical and economic studies in order to assess the nutritional, economic and environmental aspects of incorporating this product into the pelleted food for rabbits.

Finally, our work has made it possible to suggest ways to reduce the negative effects of diarrheas on the health status of rabbits after weaning.

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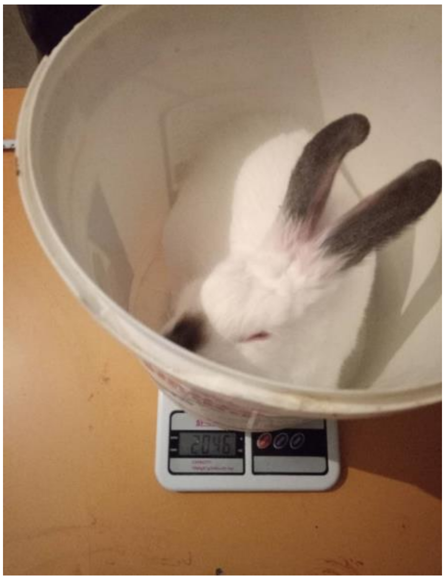
Weight of skin

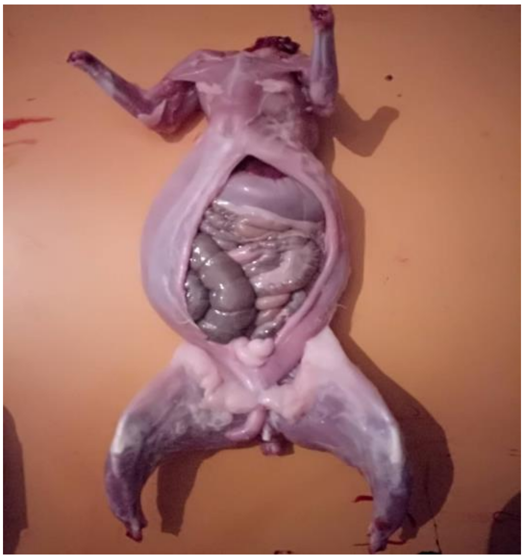
Weight of intestine

Weight of liver



Weight of rabbit

Carcass with digestive tract



Weight of carcass

Weight of total digestive tract

Weight of ceacum

Weight of stomach

Individual fattening cages

Carob pods cracked

Feces collected for the determination of digestibility

Feces and food samples for analyzis