# Soybean by-Products in the Diet of Monogastrics in Sub-Saharan Africa: "A Review"

**Alabi, C, D, A[1], Offoumon, O, T, L, F[2], Vidjannagni S, D[3], Worogo, H, S, S[4], Alkoiret, I, T[5]**

[1, 2, 3, 4, 5]University of Parakou, Laboratory of Ecology, Health and Animal Productions (LESPA), Benin
[1]*donach2[at]gmail.com*
[2]*toffoumon2001[at]yahoo*
[3]*fr svidjanaigni[at]yahoo.fr*
[4]*hilairov[at]gmail.com*
[5]*alkouarit[at]gmail.com*

**Abstract:** ***Some food resources locally available that cannot be used for human consumption deserve special attention with regard to their valorization in animal feed to ensure significant progress in animal production. Soybeans are one of the world's leading sources of animal feed with rapid growth, high nutritional value while allowing more protein to be produced per hectare. Soybean by-products are among the food resources having been the subject of several research studies in the diet of monogastrics in sub-Saharan Africa. These by-products include soybean meal, soymilk and okara (soybean pulp) which are produced through processing soybeans. By relying heavily on low-cost feed formulation to optimize the use of agricultural raw materials, these locally available by-products are the subject of fundamental choice. On the basis of a systematic documentary research, this article presents an inventory of the valuation of those soy by-products while focusing on their nutritional value, the evaluation of zootechnical and economic performance, their accessibility and availability and then, their use in the diet of monogastric in sub-Saharan Africa. Several forms of use of soybean by-products have been inventoried in the feed of monogastric, but few studies have focused on the valorization of Okara (soybean pulp). The use of these by-products in feeding monogastric has also proven to be technically and economically profitable. The study suggests options for upgrading Okara in the feed of monogastric animals to make the most this by-product locally available and better optimize production costs for monogastric farmers.***

**Keywords: S**oybeans, monogastric, by-products, Sub-Saharan Africa

## 1. Introduction

One of the major challenges for the coming decades will likely be feeding of farm animals, under the influence of strong demographic growth of the world, to the average rise in lifestyle and to the variations observed in the farming systems of which particularly the increased demand for animal products. Africa, often described as a sleeping giant when when referring to the modernization of its agriculture, presents diverse dynamics and potential for innovations, particularly in livestock systems that it is interesting to put into perspective with local changes and global and changes in livestock farming.

In the Sahel countries, animal husbandry represents nearly 40% of the GDP and the first or second pole of export (FAOSTAT, 2018). Thus, an important role is played by forages in the supply of nutrients to animals, especially protein. But, the advent of new forms of farming, much more intensive, crops (cereals, oilseeds, protein crops) as well as their by-products (bran, cakes, from milling, starch products, etc.) are widely used. By-products that cannot be used by humans are in many cases used as animal feed after industrial or sometimes artisanal separation (Moustier et al., 1999).

By using the massive formulation of lower-cost feeds to optimize the use of agricultural raw materials, several locally available by-products are selected. Feeding of the herd during dry season is one of the main obstacle to the development of the livestock sector. The natural rangelands still having fodder, constitute for the herbivorous animals, the essential feed. These rangelands are affected quantitatively and qualitatively not only by the rainfall rate but also by the evolution of the season (Sinsin, 1993). Maintaining the level of performance of animals during the deficit season and meeting the growing demand of the population for meat necessarily requires a good knowledge of the feed locally available resources.

Apart from Asia, soybeans in the last century were unknown. Nowadays, thousands of millions of people all over the world eat eggs, meat and dairy products from animals raised on soybean crops. According to Otitojou & Arene (2010), soybeans, the first source of animal feed in the world, have a high nutritional value, rapid growth and high nutritional value. It allows to produce more proteins per hectare than any other crop. In Africa, as in some countries around the world, agricultural and agro-food sector generate many by-products. Those used in livestock farming have been evaluated at 2.296.229 ton (FAOSTAT, 2018). These include soybean meal and okara which are by-products of soybean processing. The result of the use of these by-products in feeding monogastrics (rabbits, pigs, poultry) in Africa and in some countries of the world has been presented in several works.

The present study intends to reveal the various results resulting from the numerous studies to enable farmers to better understand and promote agro-industrial and agro-artisanal by-products in feeding monogastrics through this bibliographic review. This will highlight the systematics and botany of soybeans, the availability of soybean by-products, their nutritional value according to several authors in different countries of sub-Saharan Africa and the zoo-economic performances of some certain monogastrics fed with these by-products and finally to identify perspectives.

Several research works specifically theses, technical reports, online dissertations and articles, have been used in this review addressing the use of soy by-products in feeding of monogastric in sub -Saharan Africa. The documentary review was therefore the tool that was used to write this review. This bibliographic search consisted of a systematic documentary search on the technical itinerary in the following main internet sources: www.scholar.google.com ; w ww.researchgate.net ; www.aginternetwork.net ; http://www.oaresciences.org/fr/; h ttp://hal.archives-ouvertes.fr et https://www.scopus.com. All of the documents that were uploaded online were obtained after a combination of keywords. They were translated into English after their use in French to obtain maximum documents dealing with this subject. These key words were: Sub-Saharan Africa, soybeans, poultry, Okara, pigs, soybean meal, rabbits, by-products ... This exploration led to 4,938 documents of various kinds (articles, conference proceedings, thesis, dissertations, reports and statistical data). Selective sorting based on the choice of documents dealing with the sub-items developed and prioritizing scientific publications enabled to reduce the number of documents and to retain forty-eight (48) in this article. This documentation was therefore subjected to a systemic and critical analysis.

## 2. Soybean by-products for use in monogastric feed

Soybean, scientifically named *Glycine max*, is an annual herbaceous and upright plant that closely looks like beans (PADYP, 2013). Several of its by-products are used in the diet of monogastrics:

Soybean: Soybeans are mainly cultivated for their meal. Its meal is the primary product and its oil is secondary. The use possibilities for soybeans can be divided into two groups: those based on the use of the whole seed and those that start with the fractionation of soybeans into oil and cake (UNCTAD, 2016). The earliest uses of soybeans in the United States date back to 1765 mainly in Georgia State. Soybeans were grown and processed to make products for export, such as margarine. In 1917 came the discovery of soybeans used as animal feed, which led to the growth of the soybean processing industry as well as its current uses for its protein and oil. Soybeans are the most widely cultivated oilseed in the world (329 Mt). The biggest producers are the United States, Brazil and Argentina. China imports a quarter of world production. Soybeans are mainly used as animal feed in the form of flour and meal (FAO, 2017). Today, soybean production in sub-Saharan Africa is dominated by Nigeria (85%) and Benin (12%) (FAO, 2017).

In Benin, national soybean production is growing and has more than doubled in less than ten (10) years (Sèwadé, 2012); there are many products which are obtained from the processing of soybeanssuch as: mustard, flour, cheese, milk (Michaud et al., 2012). Despite the considerable interest in the use of soy products directly consumed by humans, their quantity remains relatively low (Berk et al., 1993). Soybeans, or yellow soybeans, provide the second most consumed edible oil in the world; after palm oil. From the crushing of soybeans, the main protein rich material used in animal feed is meal (Ez-Zayani, 2014).

**Soybean meal:** It is a by-product of the crushing of soybeans and is one of the main materials truly rich in protein and used in animal feed (Ez-Zayani, 2014). It is mainly used as a concentrated feed and is the most important source of protein supplement. It is the main source of protein used globally for farm animals while accounting for 2/3 of the global protein-rich raw material production (Oil World, 2010). It is the main protein material used in pig and poultry feed as a source of protein / amino acids and is also of interest in the feed of dairy cows. (Zitari, 2008). According to Britzman (1994), raw soybeans are nutritionally inferior to properly heat-treated soybeans.

Therefore, soybean meal has also become the main source of protein for poultry. For Ez-Zayani (2014), soybean meal may be incorporated in diets over 25%. However, too much soybean meal in the diet could could lead to wet droppings.

Okara: Also called soy pulp, is a fiber, by-product of soy milk, with a taste similar to coconut milk (UNCTAD, 2016). The remains of soybeans after filtering, pressing and extracting milk are called Okara. This word comes from the Japanese "Gochujang" and means "honorable shell" or "soybean Paste". It contains less protein than whole soybeans, but the remaining protein is of high quality. This product is also used to make kibbles, animal feed: rabbits and pigs. It contains most of the carbohydrates, some protein, and a small amount of soybean oil. It is a white-product, which looks like wet sawdust (Alabi et al., 2016). Okara is used as an additive for cookies and muffins, many processed foods like breads, because it gives these foods a crumbly texture. It is used in making *tempeh* cakes (sometimes called tempe gembus in Japanese). Okara is sometimes used as an ingredient in Burgers. Other uses are also in the form of the production of dry biscuits, of soy-based sausages or of ingredients in pasta for vegetarians (Shurtleff et al., 1979). It is also present in foods for certain categories of animals (MacGregor, 2000) specifically in the diet of pigs as well as bovine species. The majority of okara, which is produced in both the United States and Japan, is often used mixed with forage or hay (MacGregor, 2000). Since it is a by-product of obtaining soy milk and tofu, and therefore very much in excess of human consumption, okara is often used as animal feed. Figures 1 to 5 below show the process of obtaining okara.

**Figure 1:** *Soybeans on the grind*

**Figure 2:** *Pasty mixture from the milling*

**Figure 3 :** *Filtering device*

**Figure 4 :** *Pasty Okara.*

**Figure 5:** *Dry Okara.*

**Soy bran**: This bran is made from the husks, the outer shell of the soybean, which is removed during the initial processing. The hulls contain a fibrous material that can be extracted and then refined for use as a food ingredient (UNCTAD, 2016).

**Soy milk**: It is a more or less viscous liquid, yellowish white in color. It has a characteristic soybean smell and a bland flavor. From a nutritional point of view, it is mainly differentiated by the nature of the fat (soybeans are rich in unsaturated fatty acid while milk is rich in saturated fatty acid) and that of proteins (globulins for soybeans and caseins for milk). They are therefore complementary. Soy milk was and still is consumed all over the world. It is consumed as a diet food for vegetarians and especially vegans (Vololoniaina, 2005). It is a foodstuff that has undergone partial or total substitution in sheep feed (Toukourou et al., 2016).

## 3. Nutritional value of soybean by-products

Table 1 shows the average values of the chemical composition and the nutritional value of soybean by-products (cake, milk, remains of seeds after filtration, pressing and extraction of milk).

**Table 1:** Composition and nutritional value of by-products and soybeans

| By-product | DM (kg) | OM (g) | MM (g) | Fat (g) | TN (g) | DNM (g) | CF (g) | CE (Kcal) | DE (Kcal) | Milk feed unit | FU (/kg MS) | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soybean | 0.92 | 944.1 | 5.4 | 448.9 | 229.4 | 182.1 | 9.6 | 6707.41 | - | 1.2 | - | Montcho et al. (2016) |
| | 0.87 | 0.95 | 65 | 180 | 433 | | 6.5 | 1710 | 1371 | | | Hannachi et al. (2017) |
| | 0 .87 | | | 150 | 260 | | 7.5 | | | | | Okandza et al. (2016) |
| | 0.94 | | | 883 | 937 | | 6.1 | | | | | Ozung et al.(2017) |
| | 0.88 | | | 140 | 479 | - | | 2302 | 3429 | | | Leilane et al.(2011) |
| Soymilk | 0.92 | - | - | 23.8 | 59.3 | - | 3.8 | 580.2 | - | - | - | Toukourou et al.(2016) |
| Okara (soybean pulp) | 0.94 | 899 | 39 | 113 | 345 | - | 150 | | - | - | 0.8 | Ayéna (2016) |
| | 0.94 | - | 39 | 113 | 345 | - | 150 | 4488 | - | - | - | Attakpa et al.(2014) |
| | 0.88 | - | - | 149 | 242.7 | - | - | - | - | - | - | Silas et al.(2014) |
| | 0.92 | | | | 227 | | 113 | | 4095 | | | Tiwari et al.(2016) |
| | 0.91 | - | - | | 309 | - | - | - | 3388 | - | - | Hermann et al .(2004) |
| | 0.94 | - | 39 | 113 | 345 | - | 150 | - | 2364 | | - | Alabi et al.(2016) |

## 4. The different forms of use of soybean by-products

Several studies have been carried out around the world and particularly in sub-Saharan Africa on the valuation of soy by-products in the feed of poultry, rabbits and pigs (Table 2). Okara was the least valued while soybean meal was the most used.

**Table 2:** Summary of the forms of use of soybean by-products in the diet of monogastrics in sub-Saharan Africa

| By-product | Animal species | References | Country |
|---|---|---|---|
| Soybean | Poultry | Leeson et al. (1997) | Nigeria |
| | | Okandza et al. (2016) | Congo Brazaville |
| | | Leilane et al. (2011) | Nigeria |

| | | | |
|---|---|---|---|
| | | Aboh et al. (2011) | Benin |
| | | Odunsi A.A (2002) | Nigeria |
| | | Dongmo T. et al. (1993) | Cameroun |
| | Pig | Yao et al. (2013) | Ivory Coast |
| | | Leilane et al. (2011) | Nigeria |
| | Rabbit | Ewuola et al.(2005) | Nigeria |
| | | Ozung et al.(2017) | Nigeria |
| | | Hannachi et al. (2017) | Cameroun |
| | | A. Akoutey & M. Kpodekon (2012) | Benin |
| | | M.Dahouda et al (2013) | Benin |
| | | T. M. kpodékon et al. (2009) | Benin |
| Okara | Poultry | Attakpa et al. (2014) | Benin |
| | | Silas et al. (2014) | Nigeria |
| | | Hermann et al. (2004) | Ghana |
| | | Tiwari et al.(2016) | Ghana |
| | Rabbit | Alabi et al. (2016) | Benin |

## 5. Feed consumption and growth performance of animals fed soybean by-products

The notion of industrial by-product characterizes the secondary use of raw materials on the margins, or in addition to the main speculation for which they are produced (Wal, 1994). These products are used to supplement a basic diet consisting of fodder. For a given production objective, they are distributed in such a way for balancing the diet with regard to the animal's energy and nitrogen needs (Guerin et al., 2002). Animal feed is a way to transform and add value to certain by-products, especially soybeans. They are generally a source of essential protein intake as a supplement to energy diets based on bran or cassava. Knowledge of the nutritional effects of certain by-products on zootechnical performance requires the assessment of certain parameters such as food intake (IA), average daily gain (ADG) and Feed efficiency (CI). These three parameters vary depending on the nature and degree of incorporation of the by-product. Table 3 shows different values of these parameters with the use of soybeans and its by-products. Feed intake often varies depending on the total nitrogen content of the diet but also on animal species. So for a diet composed of 22% soybean meal (Table 3), Lesson et al. (1997) recorded a food intake (IA) of 122 g DM / d / animal for poultry while Okandza and al. (2017) report 103.01 g DM / d / animal. Regarding the Feed efficiency (CI) and the Average Daily Gain (ADG), they were 3.5 kg DM / kgBW (body weight) and 46 g / d respectively for Lesson et al. (1997) and 1.9 kg DM / kgBW and 54 g / d respectively for Okandza et al. (2017). Tabli et al., (2014) report this same value for the ADG (41g / d) even though the diet used in this experiment was composed of 30% soybean meal. In Ivory Coast , Yao et al.(XXXX), reported for experiments carried out on pigs, an IA 488 g DM / d / animal and an CI of 2.6 kg DM / kgPV for a diet composed of 8% of meal of soybean and an IA of 1654 g DM / d / animal on the one hand and an IC of 2.9 kg DM / kgPV for a diet composed of 5% soybean meal on the other hand. In 1997 in Nigeria Odunsi (2002), reported on studies carried out on poultry, a CI of 3.5 kg DM / kgPV, an IA of 104.8 g DM / d / animal and an ADG of 46 g / d with a diet composed of 27% soybean meal while in Benin, Attakpa et al.(XXXX), with a diet of 20% okara, report an AI of 114.02 g DM / d / animal an ADG of 24 g / d with an IC of 6.03 kg DM / kgBW. So the highest AI value was obtained by Lesson et al. (1997) (122 g DM / d / animal) while the smallest value was obtained by Odunsi (2002). In Benin, Alabi et al. (2018) obtained with a diet based on 10% okara in rabbits, an ADG of 18 g / d, an IC of 1.58 kg DM / kgBW and an AI of 64.16 g DM / d / animal while for a diet containing 10% soybean meal, Kpodékon et al., (2010) obtained an IA of 79.7 g DM / d / animal, an ADG of 19.7 g / d and an IC of 4.28 kg DM / kgPV. The different values thus obtained are attributable to the rate of incorporation of soybean meal or okara, the age of the animals, the type of breeding, the animal species and the sex.

**Table 3:** Growth performance of animals fed soybean by-products

| Diet based on by-products soy | Intake (g DM/j/ animal) | IC (kg DM/ kgPV) | ADG (g/j) | Specie | References |
|---|---|---|---|---|---|
| Diet composed of 30% soybean meal | 112.87 | 3.81 | 41 | Volailles | Tabli et al. (2014) |
| 20% okara-based diet | 114.02 | 6.03 | 24 | | Attakpa et al. (2014) |
| Diet composed of partially deoiled 46% soybean meal | 105 | 2.41 | 37 | | Quinsac et al. (2005) |
| Diet composed of 22% soybean meal | 103.01 | 1.9 | 54 | | Okandza et al. (2017) |
| Diet composed of 27% soybean meal | 104.8 | 3.5 | 46 | | Odunsi (2002) |
| Diet containing 22% soybean meal | 122 | 2.9 | 41 | | Leeson S et al. (1997) |
| diet consisting of 20% soybean meal | 116.8 | 2.13 | 48 | | Dongmo. et al (1993) |
| Diet composed of 7.04% soybean + 20% of Pueraria phaseoloides | 75.5 | 2.8 | 26.5 | Lapins | A. Akoutey & M. Kpodekon (2012) |
| 10% okara-based diet | 64.16 | 1.58 | 18 | | Alabi et al. (2018) |
| Diet composed of 10% soybean meal | 79.7 | 4.28 | 19.7 | | Kpodékon et al. (2010) |
| Diet composed of 2% soybean meal + Moringa Oleifera leaflets | 63.3 | 3.8 | 17 | | M.Dahouda et al (2013) |
| 2.5% soybean meal based diet | 67.8 | 3.68 | 21.5 | | T. M. kpodékon et al. (2009) |
| 2.5% soybean meal based diet | 55.92 | 3.25 | 18.67 | | T. M. kpodékon et al. (2018) |
| diet composed of 8% soybean meal | 488 | 2.6 | 188.3 | Porcs | Yao et al. (2013) |
| diet composed of 5% soybean meal | 1654 | 2.9 | 583.9 | | |
| diet composed of 11% soybean meal | 846 | 2.7 | 234 | | Leilane et al. (2011) |

**IC**: feed efficiency; **PV**: Body Weight; **ADG**: Average daily gain

## 6. Slaughter performance

The average values of slaughter performance (carcass weight and carcass yield) obtained in certain monogastrics fed with soybean by-products in sub-Saharan Africa are presented in Table 4. Several studies have presented results on the use of soybean meal in the diet of monogastrics. However very few presented results on carcass yield. In fact, Alabi et al., (2018) obtained a carcass yield of 58.22% with rabbits fed with 10% okara staple food while Dahouda et al (2013) reported a yield in carcass of 61.97% for rabbits fed with a diet composed of 2% soybean meal + *Moringa Oleifera* leaflets. Okandza et al. (2017) found a carcass yield of 71.13% for a carcass weight of 1.445 kg with a diet based on 20% soybean meal.

**Table 4:** Carcass yield of animals fed soybean by-products

| Soybean by-product diet | Weight of carcass (kg) | Carcass yield (%) | Animal species | references |
|---|---|---|---|---|
| Diet composed of 2% soybean meal + *Moringa oleifera* leaflets | - | 61.97 | Rabbit | M.Dahouda et al. (2013) |
| 10% okara-based diet | 0.809 | 58.22 | | Alabi et al. (2018) |
| Diet based on 20% soybean meal | 1.445 | 71.13 | Poultry | Okandza et al. (2017) |

## 7. Economic balance

The use and recovery of some soybean by-products contribute to reducing feed costs. Thus, the use of okara in the feed of poultry and rabbits results in a relatively large reduction in feed expenditure. Some results are shown in Table 5 below. Several authors (Alabi et al., 2018; Attakpa et al., 2014) substituting soybean meal with okara in rabbits and poultry respectively, obtained a higher profit margin. Attakpa et al. (2014) obtained a profit margin of 518F CFA by incorporating okara up to 20% in the poultry diet compared to a margin of 273F CFA with an incorporation of okara at 10%. In addition Alabi et al. (2019) reported that the use of 10% okara in the diet of rabbits had generated a profit margin of 741.49 F CFA against a profit margin of 546.64 F CFA with rabbits fed a diet of 10 % soybean meal.

**Table 5:** Economic profitability

| Diet based on by-products | Food cost by Subject (F CFA) | Net benefic (FCFA)/ animal | Animal species | References |
|---|---|---|---|---|
| Diet composed of 10% soybean | 834.61 | 546.64 | Rabbits | Alabi et al. (2019) |
| Diet composed of 10 okara | 651.76 | 729.49 | | |
| Diet composed of 10% soybean meal | - | 472 | | Kpodékon et al. (2010) |
| Diet composed of 7.04% soybean + 20% of *Pueraria phaseoloides* | - | 305 | | Akoutey & M. Kpodekon (2012) |
| 2.5% soybean meal based diet | - | 33 | | kpodékon et al. (2009) |
| 2.5% soybean meal based diet | - | 75.3 | | kpodékon et al. (2018) |
| Diet composed of 20% of okara | 715 | 518.8 | poultry | Attakpa et al. (2014) |

## 8. Some anti-nutritional factors of soybeans

The soybean contains anti-nutritional factors, the most important and the most studied for their impact on physiology are:
Soybeans in large quantities in diets enriched with urea for ruminants can lead to ammoniacal poisoning, as the microbial flora cannot assimilate all of the ammonia produced (Evrard et al., 2003).

Phyto-hemagglutinins are abundant in soybeans. These are toxins that interfere with the normal absorption of pancreatic amylase and subsequently lead to rapid elimination of the enzyme in the feces (Zitari, 2008).

Whole crushed soybeans can be used in limited quantities on ruminants. As the anti-nutritional factors of crushed soybeans are destroyed by fermentation in the rumen, there is no anti-trypsin effect. The limitation comes from the total amount of fat content which must not exceed 5% of the dry matter (DM) ingested (take into account the possible contribution of lipids from corn silage), i.e. a maximum intake of fat of 0.8 to 1 kg per 20 kg of ingested DM (Evrard et al., 2003).

**Protease inhibitors**: the ingestion of raw soybeans leads to an alteration in protein digestion by inhibiting two digestive enzymes secreted by the pancreas (trypsin and chymotrypsin), responsible for the digestion of food proteins. Feed efficiency deteriorates, resulting in reduced growth of animals. There are two main tryptic inhibitors: Kunitz factor, thermolabile, and Bowman-Birk factor, which is much more stable. The average antitrypsic activity of soybeans is 39 ITU / mg (ITU: international tryptic unit) but it may vary significantly depending on the origin of the soybean (3.4 to 71 ITU / mg).

**Hemaglutinins or lectins:** these substances, the best known of which are ricin from castor bean, soybean from soybean and phasin from bean, have the ability to bind to the cells of the intestinal mucosa (microvilli membranes) and thereby prevent the intestinal absorption of amino acids, vitamin B12 and polysaccharides. They are thermolabile.

## 8. Availability of soybean by-products in sub-Saharan Africa

Although still marginal, soybean is a relatively recent crop, , gaining more importance in sub-Saharan Africa. One could say that in most cotton-producing countries, peasants are moving a lot towards this production which tends to make them more independent in almost all their commercial transactions, unlike that of cotton. As can be seen in Burkina Faso and Benin in particular (Figure 6), productions have increased sharply, as a response (or a consequence) to the fall in cotton (FAO, 2017). In Benin, annual soybean production was estimated at 13,218 tons in 2007 but since then it has practically quadrupled to 55,259 tons in 2009 thanks to various reforms undertaken by the government of Benin (MAEP, 2010). Since then, this production has doubled to 156,901 tons in 2016 and is growing steadily. Depending on the geographical distribution, the production of this legume is much more concentrated in the departments of Collines and Borgou. This is explained by a perfect acclimatization of this plant in the area (MAEP, 2010).

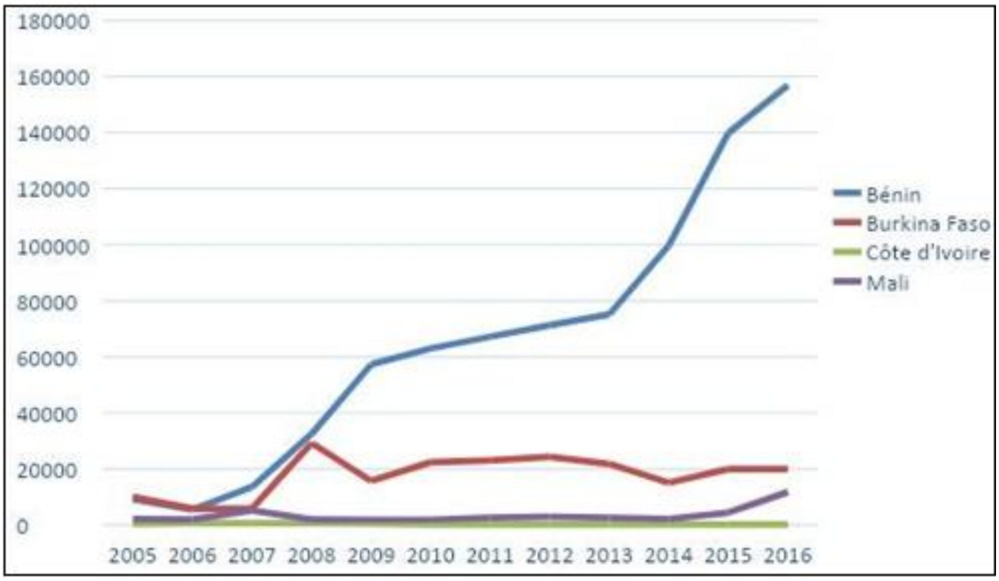


**Figure 6**: Evolution of soybean production in the UEMOA region (ton) Source: FAO, 2017

The use of certain agro-industrial and agro-artisanal by-products such as soybean hulls and okara, of which availability, accessibility and cost are not limiting factors, could be a solution. In the literature, detailed knowledge of these locally available by-products is lacking. Hence the great need for this review

## 9. Involvement

Knowledge of locally available soy by-products should allow them to be better valued in the feed of farm animals in general and in particular in the feed of monogastrics to maintain a level of performance of the animals and reduce costs of production. In addition, the knowledge of their nutritional value can enable to formulate interesting diets and at lower cost for animals. The use of soybean by-products therefore improves the zootechnical performance of animals and also heightens the value of its by-products.

## 10. Perspective

All the data used for this review relate to soybean by-products in the diet of monogastrics. Feed diets from locally available by-products (especially okara) should be tested on some of these monogastrics and the diets that have produced the best

## 11. Conclusion

The synthesis of knowledge on the valuation of agro-industrial by-products in feeding monogastrics in sub-Saharan Africa has shown that several agro-industrial or artisanal soy by-products are used. Among these by-products, okara is the least used by-product. However, today, soy has entered the dietary habits of rural populations in Africa, the by-products of its local processing (okara) constitute a raw material that is frequently available and accessible. Development in the diet of monogastrics in sub-Saharan Africa has shown that several agro-industrial or artisanal soy by-products are used. Therefore, this by-product should be of renewed interest in terms of its nutritional value and be the subject of an in-depth study in the diet of monogastrics. Thus, at national and regional levels, innovative research projects must be undertaken in a concerted manner at each level of the soybean production chain or line.

## Acknowledgments

The authors are grateful to to the Beninese Government for financial support throughout the PhD student support program granted to Alabi C.D.A

## References

[1] Aboh A. B., Ehouinsou M. A., Olaafa M. & A Brun A., 2008. Complémentation alimentaire des ovins Djallonké avec les sous-produits de transformation d'ananas : potentiel nutritif, préférence et développement pondéral. Bul. Rech. Agr. du Bénin, 61, 25-30.

[2] Akoutey A. & Kpodekon M., 2012. Performances zootechniques de lapereaux recevant des aliments granulés contenant du Pueraria phaseoloides. TROPICULTURA, 2012, 30, 3, 161-166

[3] Attakpa Y.E., Aplogan I. G., Akossou A.Y.J. & Bosma

R. H., 2011. characteristic and health of TurKey Husbanry in Ouaké, north-Benin. INRN Veterinary Science, 4p.
[4] Cham Donald Adégbéïga Alabi, et al., 2018 : Effect of soybean meal substitution with okara in growing rabbits in fattening phase in northern Benin. International Journal of Agronomy and Agricultural Research (IJAAR) Vol. 13, No. 3, p. 1-10, 2018
[5] Alabi C. D. A., et al., 2019. Effet de la granulation d'un aliment avec pulpe de soja (okara) sur l'engraissement de lapins locaux au Nord-Bénin. Livestock Research for Rural Development. Volume 31, numero 5 Article #65. Retrieved April 30, 2019, from http://www.lrrd.org/lrrd31/5/donac31065.html
[6] Ayéna J. A., 2016. Performances de croissance des ovins Djallonké complémentés avec l'Okara à Djougou au Nord-Ouest du Bénin. Mémoire pour l'obtention du diplôme de Master professionnel, Université de Parakou, Bénin, 80p.
[7] Attakpa, E. Y., C. G. Akouedegni., Dossou T. R. & Alkoiret I. T., 2014. Effect of Okara (Soy Pulp) on the Performance of Rhodes Island Red (RIR) in Republic of Benin. Journal of Animal Science Advances, 4 (7): 949-954.
[8] Berk Z., 1993. Technologie de production de farine alimentaire et de protéine issus du Soja. Bulletin des services agricoles de la FAO, 97, Rome/Italie, 133p.
[9] Britzman D., 1994. On refusing explication : A non-narrative narrativity. Paper presented at the annual meeting of the American Educational Research Association. New Orleans, LA, 248 p.
[10] CNUCED (Conférence des Nations Unies sur le Commerce Et le Développement), 2016. SOJA. 25p.
[11] Dahouda M., et al., 2013. Effets des aliments contenant les folioles de Moringa oleifera Lam et des aliments commerciaux sur les performances de croissance des lapins (Oryctolagus cuniculus) et la qualité de la viande. / Int. J. Biol. Chem. Sci. 7(5): 1838-1852, 2013
[12] Dongmo T., M Pouilles-Duplaix, J D Ngou Ngoupayou, E Blesbois et M. De Reviers (1993) : Utilisation du tourteau de coton dans l'alimentation des volailles. Étude zootechnique chez les reproducteurs de l'espèce Gallus domesticus. Revue Elev.Méd vét. Pays trop., 1993 46 (4) : 609-619
[13] Evrard J., Baudet J-J., 2003. Graines entières de soja : de l'énergie et des protéines. Fiche technique, Ed CETIOM, 4p.
[14] Ewuola A., Nianogo A. J., Ouedraogo T. & Somda J., 2005. Use of local feed resources in the farmers ram fatting scheme: technical and economical performance. Cahiers Agricultures, 17, 24-27.
[15] Ez-Zayani L., 2014. Processus de préparation et d'extraction d'huile de soja et les analyses du tourteau. Mémoire pour l'obtention du diplôme de licence en biotechnologie, hygiène et sécurité alimentaire. Faculté des sciences et techniques de l'université Sidi Mohammed Ben Abdellah, Maroc, 43p.
[16] FAO (Food and Agriculture Organisation., 2017. Résidus agricoles et sous-produits agro-industriels en Afrique de l'ouest : Rapport sur l'état des lieux et perspectives pour l'élevage, 73p.
[17] FAOSTAT (Statistical of Food and Agriculture Organization), 2018. Data from the FAOSTAT Statistical data base. www.fao.org
[18] Guerin H., Lecompte P., Lhoste P., & Meyer C., 2002. Généralité sur les ruminants. In : Mémento de l'Agronome. MAE-CIRAD-GRET, 1313-1324
[19] Hermann J-R., Honeyman & Mark S., 2004. Okara :A possible High Protein Feedstuff for organic pigs Diets ''Animal Industry DOI: https://doi.org/10.31274/ans_air-180814-197
[20] Koffi S., Yao A., Moussa K., Dofara S. & Fantodji A. 2013. Effet de l'incorporation de la noix de cajou dans les rations alimentaires sur les performances de croissance des porcs : phases post-sevrage et de croissance. Int. J. Biol. Chem. Sci. 7(2): 479-488, April 2013.
[21] Kpodékon T. M., et al. 2009. Comparaison des performances de croissance de lapereaux en engraissement nourris par un aliment à base de tourteau de tournesol, soit sous forme farineuse soit sous forme granulée. Livestock Research for Rural Development 21 (12) 2009
[22] Kpodekon T. M., et al., 2010. Influence de la teneur en tourteaux de coton de l'aliment d'engraissement sur les performances de croissance des lapins. Bulletin de la Recherche Agronomique du Bénin Numéro 68 – Décembre 2010.
[23] T M Kpodékon., et al., 2018. Substitution du tourteau de palmiste par le tourteau de tournesol dans l'alimentation des lapins à l'engraissement http://www.lrrd.org/lrrd21/6/kpod21092.htm
[24] Leeson S., Caston L., Summers J.D., 1997. Layer performance of 4 strains of Leghorns subjected to various rearing program. Poultry Science, 76: 1-5.
[25] Leilane R. B. D et al., 2014. Soybeans (Glycine max) and Soybean Products in Poultry and Swine Nutrition. Small-Scale Forestry, 8(1), 25–42.
[26] MacGregor C. A., 2000. Directory of feeds and feed ingredients. Hoard's Dairyman Books, W. D. Hoard and Sons Company, ISBN: 13: 978-0932147349, 95p.
[27] Michaud A. & Vodouhè G., 2012. L'émergence des innovations au Bénin: cas du soja et des produits dérivés de grande consommation. FSA, CIRAD, JOLISSA. Rapport d'étude, 47p.
[28] Montcho M. S., et al., 2016. Disponibilité, valeurs marchande et nutritionnelle des sous-produits agricoles et agroindustriels utilisés dans l'alimentation des ruminants au Benin. European Scientific Journal November 2016 edition Vol. 12, No33 (2016) ISSN : 1857 - 7881 (Print) e - ISSN 1857 – 7431, 20 p.
[29] Moustier P., Mbaye A., De Bon H. & Guerin H., 1999. Agriculture périurbaine en Afrique subsaharienne. CIRAD Colloques. Montpellier : CIRAD éditions, 276 p.
[30] Odunsi A. A., 2002. Effect of feeding rejects cashew kernel meal on pre and early- laying performance of pullet. Archives Zootechnic, 5: 423-429.
[31] Oil World., 2010. Le tourteau de soja. Consulté le 17/07/2020 à 15h 34 sur le site web http://www.terresunivia.fr/produitsdebouches/alimentati

on-animale/tourteaux-d-oleagineux.
[32] Okandza Y., et al., 2017. Influence de la substitution graduelle de tourteau de soja par la féverole sur la croissance et la conformation de la carcasse chez les poulets de chair. http://dx.doi.org/10.4314/jab.v110i1.2
[33] Otitoju M. A., & Arene C. J., 2010. Constraints and determinants of technical efficiency in medium-scale soybean production in Benue State, Nigeria. Afr. J. Agric. Res. 5 (17): 2276-2280.
[34] Ozung P. O., et al., 2017. Growth Performance and Apparent Nutrient Digestibility Coefficients of Weaned Rabbits Fed Diets Containing Different Forms of Cocoa Pod Husk Meal. Agriculture and Food Sciences Research, 4(1):
8-19.
[35] PADYP (Programme d'Appui aux Dynamiques Productives), 2013. Fiche technique de la culture du soja, Bénin, promotion de modèles d'élevages à cycles courts de lapins, volailles et aulacodes (PPMECC). Cotonou, FAO, 77p.
[36] Quinsac al., et al., 2005. Intérêt de différents tourteaux de soja partiellement déshuilés par extrusion-pression, pour l'élevage de poulets «label». Perspectives d'avenir. Cuni-Sciences, 4, 2, 15 à 26.
[37] Rabia H., et al., 2017. La graine de fève sèche (Vicia faba major L) en alimentation cunicole: effets sur les performances de croissance et d'abattage. Livestock Research for Rural Development volume 29 N°3 2017
[38] Sèwadé P., 2012. Note conceptuelle du consortium soja au Bénin, Cotonou, FAO, 77p.
[39] Shurtleff W., & Aoyagi A., 1979. The Book of Tempeh. Soyinfo Center. ISBN 0-06-014009-7, 114p.
[40] Sinsin, B., (1993) : Phytosociologie, écologie, valeur pastorale, production et capacité de charge des pâturages naturels du périmètre Nikki-Kalalé au Nord-Bénin. Thèse de Doctorat en sciences agronomiques : Université de Bruxelles, Belgique, 390p.
[41] Tabli A., Elhaitoum A. & Tafiani C 2014. Le soja dans l'aliment du poulet de chair. chickens. Poult. Sci, 68, 185-189.
[42] Tilas M. E., et al., 2014. Reversibility of there productive toxicity of gossypol in peripubertal bulls. Theriogenology, 61 (6): 1171-1179.
[43] Toukourou Y., Abdoulaye M., Attakpa Y. E., & Alkoiret I. T. 2016. Croissance des agneaux Djallonké nourris avec le lait de soja. Tropicultura, 34 (2): 150-157.
[44] Tiwari P., & Rajesh J., 2016. Nutrient profile and digestibility of tubers and agro-industrial coproducts determined using an in vitro model of swine https://doi. 10.1016/j.aninu.2016.07.004
[45] Vololoniaina S. M., 2005. Valorisation du lait de soja en fromagerie : Cas de la fabrication de « soycheeses » dans la région de Vakinankaratra. Mémoire d'ingénieur Agronome, Université d'Antananarivo, Antananarivo, Madagascar, 134p.
[46] Wal G., 1994. Le coton et ses co-produits en alimentation animale. Revue de l'Alimentation Animale, 482, Novembre, 3p.
[47] Wal. J-M. 1994. Utilisation des sous-produits industriels en alimentation animale à Madagascar (Slovak J. Anim. Sci., 47, 2014 (1): 51-60© 2014 NPPCISSN 1337-9984)
[48] Zitari S., 2008. Etude des valeurs nutritives de certaines ressources alimentaires locales utilisées dans l'alimentation des animaux. Mémoire de Master, Université de Sousse, Tunisie, 58p.

## Author Profile

**Cham Donald ALABI** is Phd Student. He is staying in Benin and working as a Research Assistant at the Laboratory of Ecology, Health and Animal Productions (LESPA) at University of Parakou.