1. INTRODUCTION

The world’s population is continuously increasing and accordingly, demand for food is growing. The United Nations of Food and Agriculture Organization (FAO) predicts that the global population is expected to reach approximately 9.7 billion by 2050 and will need to be fed with billions of livestock (ANSE, 2015). Responding to the growth population, the demand for animal source will continue to grow to reach 70% by 2050 (IFIF, 2018). Consequently, the world supply of some conventional feedstuffs like soybean and maize will increasingly compete between humans and livestock. Therefore, a crucial challenge for the future years is the discovery of new and sustainable protein sources, energy and other nutrients for animal feeds.

Poultry is one of the fastest growing agricultural sub-sector, as a result of changes in consumption patterns, poultry meat is the most widely consumed in the world during the last decades. Over the last 5 decades, the average annual growth rate was 5% for poultry meat in comparison to beef (1.5%) and pork meat (3.1%) (FAOSTAT, 2016a). While beef and pork demand could increase by 66% and 43% respectively, poultry meat is expected to have the highest growth, with 121%. poultry meat production would however increase at a slower rate than in the past decades. By 2050, its annual growth rate is estimated to reach 1.8% at global level, and 2.4% in developing countries (FAOSTAT, 2016a).
Soybean meal (SBM) is the most widely used protein source in the formulation of poultry diets, with a recorded global world production of about 300 million tons in 2016 (FAOSTAT, 2016b). However, the production and supply of this conventional protein source is not sufficient to meet the increasing requirements of the expanding and fast-growing poultry industry, which resulted in an inappropriate increase in the price of poultry feed and ultimately affected the growth of the poultry industry (Ukachukwu, 2007). This means that the production of SBM must increase beyond current production level of about 246 million metric tonnes (FAS/USDA, 2009). Nowadays, the production and utilization of SBM for animal feed is bound to face future challenges as a result of increased demand of vegetable oil for biofuel production and its ever-increasing price. Thus, there is a need to overcome these challenges and to explore potential SBM alternatives.

To meet the protein demands in the poultry sector, the recent research trends are being focused toward finding out an alternative source of protein ingredient. Insects are currently perceived as a possible and promising alternative dietary protein source for monogastric animals (Makkar et al., 2014; Sánchez-Muros et al., 2014; Henry et al., 2015), due to their chemical composition, with an adequate AA profile, lipids and other valuable nutrients such as vitamins and minerals, high feed to protein conversion rate, great acceptance by poultry, whose diet in nature is partly represented by insects, potentially low environmental impact, low space requirement for production and their claimed sustainability (Spranghers et al., 2017a, Spranghers et al., 2017b).

The potential of insect protein in poultry diets has received more attention and research efforts with promising results obtained (Biasato et al., 2016, 2017, 2018; Cullere et al., 2016 and 2018; Cutrignelli et al., 2018; De Marco et al., 2015; Dabbou et al., 2018; Loponte et al., 2017; Ruhnke et al., 2018; Schiavone et al., 2017a; Secci et al., 2018; Velten et al., 2018; Mwaniki et al., 2018). Therefore, it is seems reasonable to consider the inclusion of insect proteins as raw material to be used in commercial feed manufacturing of poultry. Insect meals are not allowed to be included in livestock and poultry feeds in Europe until now (Vantomme, 2015). Nonetheless, since 1 July 2017, processed insect protein has been authorized for the use in aquaculture by Regulation (EC 999/2001; EU, 2017). Therefore, the EU legislative barriers are expected to be overcome in the future in order to include this alternative and promising protein source in the poultry diets.

2.- NUTRIENT COMPOSITION OF INSECTS

Insects could be a potential future response to the increasing amount of feed required by animal nutrition (van Huis et al., 2013). Moreover, insects have a high nutritional value. They are rich in proteins with high biological value which can range between 42 to 63% and similar when compared with that of SBM (45-50%). However, crude protein (CP) contents are slightly lower than that in fishmeal (FM; 60- 80%) (Finke 2002; Makkar et al., 2014; Sanchez-Muros et al., 2014; Payne et al., 2015). Insects are also
rich in fat contents, which can vary from 7.9% to 40% (Finke 2015; Meneguz et al., 2018), vitamins and minerals (van Huis et al., 2013). However, the chemical composition and the nutritional value of insect larvae meals largely depend on varying species, phases of development (adult, larva or pupa), the treatment (i.e. drying methodologies, defatting procedures) and on the rearing substrate (Henry et al., 2015; Sánchez-Muros et al., 2014). The CP content of larvae meal could be increased by over 60% when protein and fat are separated (Sheppard et al., 2007). The defatting process increases the CP and decreases the lipid value of the insect meal, which may lead to total or partial destruction of AA such as cysteine, tryptophan and methionine (Castell et al., 1986).

The five major insect groups that can be potentially used as standard ingredients in animal feeding are represented by black soldier fly (*Hermetia illucens* L.; HI), housefly (*Musca domestica* L., MD), yellow mealworm (*Tenebrio molitor* L., TM), locusts-grasshoppers-crickets and silkworm.

2.1. Black soldier fly (*Hermetia illucens* L.)

The protein content of full and defatted HI larvae meal varied between 35.30 and 72.50% of dry matter (DM). The defatting process may further influence the protein content, with the obtaining of higher values than SBM and FM. HI have a better AA profile than SBM (Barragan-Fonseca et al., 2017), but it appears that contents of some AAs change in relation to larval rearing substrate. Essential AA levels in larvae produced on swine manure are similar to SBM in lysine, leucine, phenylalanine, and threonine (Newton et al., 2005). In particular, HI larval protein is rich in lysine (6-8% of protein content) (Sheppard et al., 2008). Barragan-Fonseca et al. (2017) showed that HI larvae contain higher contents of alanine, methionine, histidine, and tryptophan, and a lower content of arginine than SBM. In addition, they contain a greater amount of lipids (15% to 49%), which can be isolated and used for the preparation of biodiesel, while the rest of the defatted meal could be used as a protein rich source for the feed industry. The composition and amount of lipids in insects vary according to the species, sex, development stage, rearing substrates and processing methods (Paul et al., 2017; Makkar et al., 2014; Tzompa-susa et al., 2014). The fatty acid (FA) composition of the HI larvae depends on the FA composition of the diet. HI lipid content ranges from less than 10% to more than 30% on a fresh weight basis and contains a higher amounts of unsaturated fatty acids (UFA) (DeFoliart, 1991). HI larvae and prepupae have been found to contain 58-72% saturated fatty acids (SFA) and 19-40% mono- (MUFA) and polyunsaturated fatty acids (PUFA) of total fat content (Kroeckel et al., 2012; Makkar et al., 2014; Surendra et al., 2016;) with a higher level of lauric, palmitic and oleic acid (Surendra et al., 2016). HI larvae also contain around 5% calcium, much higher than many insect species (Khusro et al., 2012). Cullere et al. (2016) reported that the most abundant essential AAs were valine and leucine, whereas alanine and glutamic acid were rich in defatted HI larvae meal. HI larvae also contain chitin, which is not digestible by monogastric animals (Sánchez-Muros et al., 2014), and it can negatively affect protein digestibility (Longvah et al., 2011).
2.2.- **Yellow mealworm (Tenebrio molitor L.)**

The yellow mealworm (*Tenebrio molitor* L.) is a worldwide distributed coleopter belonging to the Tenebrionidae family (Makkar et al., 2014). Yellow mealworms are already industrially produced as feed for pets and zoo animals, such as birds, reptiles, small mammals, amphibians and fish (Makkar et al., 2014). TM larvae are easily bred on dried waste materials, being able to recycle them into high-quality feed with less energy cost, land area utilization and footprints (Makkar et al., 2014). Larval and pupal stages of TM are rich in protein and easy to breed and feed. The meal derived from TM larvae has a high content of CP, which ranges between 44 and 69% (Ravzanaadii et al., 2012; Veldkamp et al., 2012; Gasco et al., 2016). The AA composition is similar to that of SBM, with the exception of the methionine content, which may limit the use of TM in poultry feeds (Ramos-Elorduy et al., 2002). In addition, TM contains fat (8–33% dry basis) varies between 8 and 47% (Ravzanaadii et al., 2012; Veldkamp et al., 2012; Gasco et al., 2016), minerals and vitamins (De Foliart et al., 2009). The lipid fraction of TM is characterized by high levels of oleic (42.18% FA), linoleic (24.70% FA) and palmitic (18.42% FA) acids. TM larvae contains a higher amount of phosphorus and a lower amount of calcium (Ravzanaadii et al., 2012) which can be modified through the rearing substrate (Anderson 2000; Klasing et al., 2000).

2.3.- **Housefly (Musca domestica L.)**

The housefly (*Musca domestica* L.) can be used to convert waste to high protein feedstuff since the last decades (Miller, 1974). MD larvae meals have a protein content ranging from 37.5 to 63.8% of DM with higher amount of threonine and leucine (74 and 83 % of lysine, respectively) (Hussain et al., 2017; Józefiak et al., 2016; Makkar et al., 2014; Zuidhof et al., 2003; Aniebo and Owen 2010). Hussain et al. (2017) demonstrated that the AA profile of MD larva meal was better balanced than SBM and fish meal (FM) with no limiting AAs. MD larva meal had higher content of methionine, phenylalanine and tyrosine compared to both SBM and FM (Hussain et al., 2017; Sánchez-Muros et al., 2014). The lipid content of MD larvae meal ranging between 6.28 to 31.30% of DM (Aniebo and Owen 2010; Makkar et al., 2014; Zuidhof et al., 2003). The FA profile contains higher amounts of saturated and monounsaturated FA (57.5 % and 38.64% FA; respectively) and lower amounts of polyunsaturated FA (3.86% FA) (Hussain et al., 2017). This profile is very rich in palmitic (32.37% FA), oleic (21.96% FA), linolenic (19.70% FA) and palmitoleic (17.10% FA) acids (Gasco et al., 2018). The calcium and phosphorus content of MD larva meal were higher than that observed in SBM, but much lower than values observed in FM using cattle manure as substrate (Hussain et al., 2017). Makkar et al. (2014) showed that the calcium content (about 4.7 g/kg DM) is higher than that of the TM larva but lower than that of HI.
3.- USE OF INSECT LARVAE MEAL IN POULTRY DIETS

3.1.- Effect on digestibility coefficient

There is very limited information available on the impact of insect larvae meals on broiler chicken digestibility. The digestibility of HI and TM proteins and their utilization in vivo have shown promising results. De Marco et al. (2015) and Schiavone et al. (2017a) showed a moderate apparent digestibility coefficient (ADC) of the total tract of CP of full-fat (51%), partially defatted (62%) and highly defatted (62%) HI larvae meal in broiler chickens. The same authors also reported an apparent ileal digestibility coefficient (AIDC) of AA ranging from 42 to 89% for the full-fat meal (De Marco et al., 2015), from 44 to 92% for the partially defatted meal and from 45 to 99% for the highly defatted meal (Schiavone et al., 2017a). The AIDC of AA in the study of Schiavone et al. (2017a) were higher than those reported for other animal protein sources (feather meal, meat meal and meat and bone meals) and were similar to those obtained for FM (Ravidran et al., 2005), also for the most limiting AA such as lysine, methionine and threonine. These studies showed the effectiveness of the defatted insect meal seems related to a better efficient nutrient digestion. Regarding the use of TM in broiler chickens diets, De Marco et al. (2015) have reported high ADC of the total tract of CP (60%) and high AIDC of AA (80-93%) of full-fat TM meal. TM showed more digestible EE (99%) than that of HI meal (88%) in the study of De Marco et al. (2015). In vitro organic matter and nitrogen digestibilities of TM were found as 91.5 and 91.3%, respectively according to Bosch et al. (2014).

In the study of Hwangbo et al. (2009), broilers fed diet with MD larva meal have a very high ADC of CP (98%). Pretorius (2011) tested dried MD larva meal in broiler chickens diet found a 69% of CP digestibility. The latter study also showed that CP fecal digestibility was greater for MD pupae than for the larvae. Recently, Bosch et al. (2014) reported in vitro digestibilities of organic matter and nitrogen in MD fly pupae were found as 83.2 and 84.3%, respectively.

The reduction of the nutrient digestibility when using insect meals in poultry feeds is due to their high chitin content. Although chickens have been shown to produce chitinase in the proventriculus and hepatocytes (Suzuki et al., 2002), the digestibility of chitin seems to be limited (Hossain and Blair, 2007). Chitin content can inhibit nutrient absorption from the intestinal tract and thereby reduce fat and protein absorption in broiler chickens (Razdan and Pettersson, 1994; Khempaka et al., 2011; Bovera et al., 2015). Previous studies reported that chitin negatively influence the nutrient digestibility of CP (Razdan and Pettersson, 1994; Hossain and Blair, 2007) and organic matter (Razdan and Pettersson, 1994). Indeed, Marono et al. (2015) indicated that chitin is the main factor affecting the in vitro protein digestibility of HI meal and showed that CP digestibility was negatively correlated to the chitin content. Research has shown that extraction process, partial chitin removal through high pressure processing and dietary enzyme inclusion could...
reduce the content of chitin and improve the use of insects as feeding ingredient (Rumpbold and Schlüter, 2013; Sánchez-Muros et al., 2014; Henry et al., 2015).

3.2.- Effect on growth performances

3.2.1.- HI larvae meal

Insects are considered as a potential substitute for FM and SBM in poultry feeding with a good palatability (Makkar et al., 2014; Sánchez-Muros et al., 2014). HI larvae meal are the most widely used and the earliest studied as protein source in poultry feed (Hale, 1973). The latter study showed that chicks fed a diet containing dried HI larvae (as a substitute for SBM) gained weight at a rate 96% (even if non-significant) of that of birds fed the control diet, but they only consumed 93% (significant) as much feed. Oluokun (2000) showed that HI could replace FM in the broiler diets without any adverse effect on the body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR). Using partially defatted HI larvae meal with 10% and 15% inclusion levels as partial replacement of SBM and oil in growing broiler quails, Cullere et al. (2016) observed unaffected BWG, FI and FCR. The authors performed a feed-choice test in broiler quails and observed that the birds tended to prefer the diets including HI larvae meal. The replacement of SBM with 25 and 50% of HI meal (100 and 190 g/kg of inclusion respectively) in Barbary partridge (Alectoris barbara) resulted in a higher final weight and better feed efficiency compared to the control diet (Loponte et al., 2017). Recently, Dabbou et al. (2018) showed that the inclusion up to 150 g/kg as fed of partially defatted HI larvae meal in the broiler chickens diet, affected the final LW of the animals, with a lower LW for the birds fed with the maximum level of HI in the diet, while no differences were observed when birds were fed with 100g/kg of HI in the diet. The authors observed an improvement of FI during the starter period with a maximum for the inclusion of 100g/kg of HI in the diet but a worsening in the FCR during the growing and finishing periods. The results of Dabbou et al. (2018) showed that low inclusion levels may be more suitable for boiler chicken diets.

In laying hens, no significant differences was observed using diets containing partly defatted meal of dried HI larvae as partial or complete replacement of soybean cake (Maurer et al., 2016). Al Qazzaz et al. (2016) also reported unaffected or improved growth performance and productivity in laying hens fed diets supplemented with 1% or 5% of HI larva meal. However, laying hens fed diets in which the SBM was completely replaced by HI larvae meal showed a more favorable FCR than birds fed the control diet, but lower lay percentage, feed intake, average egg weight and egg mass (Marono et al., 2017). Secci et al. (2018), testing the effect of 100% replacement of SBM with HI larva meal in the diet of laying hens (Lohmann Brown Classic) for 21 weeks, showed a higher proportion of yolk in the eggs in HI group with higher amount of γ-tocopherol, lutein, β-carotene and total carotenoids than SBM group. Mwaniki et al. (2018) showed that the inclusion up to 7.5% defatted HI larvae meal in a corn–SBM diet fed to pullets (19 to 27 wk of age) an increased FI, FCR, yolk color, egg shell-breaking strength and thickness.
Above all these previous studies, insect larvae meal can be suitable ingredients for broiler chicken and laying hens diets.

3.2.2. - TM larvae meal

Soybean meal replacement with TM meal has been investigated in poultry diets extensively in the last few years. Ramos-Elorduy et al. (2002) showed no effects for the growth performance in fast-growing chickens fed sorghum-SBM-based diets in which the full fat TM inclusion level ranged from 5 to 10% in partial substitution of SBM and vegetable oil. Ballitoc and Sun (2013), observed a decreasing trend in FCR when TM larvae meal was added from 0 to 10% in a broiler diet. Full fat TM larva meal might be included at a dietary concentration of 7.5% in free-range chicken diets in complete substitution of corn gluten meal (Biasato et al., 2016), without affecting growth performances. In female and male broiler chickens fed dietary increasing levels of full fat TM meal inclusion (50, 100 and 150g/kg) with a partial replacement of SBM, corn gluten meal and soybean oil, Biasato et al. (2017 and 2018) showed an improvement in body weight and FI with increasing levels of TM meal inclusion, but the feed efficiency resulted partially impaired. In the contrast, Bovera et al. (2015 and 2016) found an improvement in FCR in broiler chickens fed on a corn-SBM based diets in which the 29.65% of SBM was completely replaced by TM meal.

Based on the results of above studies, it seems that TM larvae meal could replace the conventional protein sources, in particular SBM, in broilers chicken diets.

3.2.3. - MD maggot meal

Previous studies conducted on including MD maggot meal in poultry diets (Téguia et al., 2002; Awoniyi et al., 2003; Adeniji, 2007; Hwangbo et al., 2009; Pretorius, 2011; Okah and Onwujiariri, 2012; Khan et al., 2017), layers (Dankwa et al., 2002; Agunbiade et al., 2007) and ducklings (Mensah et al., 2007) are available in literature. All the studies suggest that MD could replace conventional protein sources, particularly FM, with an optimal inclusion level lower than 10% in the diet (Makkar et al., 2014). An imbalanced AAs profile and darker colour of the meal may explain the negative effects observed when the inclusion levels are greater than 10% (Makkar et al., 2014). The effect of MD maggot meal on the performance of birds might depend on the nutrient profile of the larvae meal, and also on the amount of dietary FM in the reference diet. Téguia et al. (2002) obtained higher BWG with increasing inclusion level of MD meal (5, 10 and 15%) as compared to conventional FM during the grower-finisher periods of broiler chickens. Similarly, an improvement in growth performance was observed when broiler fed 10 and 15% of MD maggot (Hwangbo et al., 2009). In addition, Okah and Onwujiariri (2012) reported that the chickens fed the 20 and 30% of MD maggot meal in replacement of FM have higher BW than those fed the control diet. In the same context, Khan et al. (2017) also observed that broiler chickens fed MD meal diet showed higher BW and lower FCR in comparison with those fed SBM diet. On the other hand, Pretorius, (2011) showed that MD larvae in broiler
chicken diets may be added at approximate dietary levels of 25% DM, without any negative effects on BWG, FI and FCR. Adeniji (2007) did not find significant differences in growth performances with inclusion levels ranging from 5.5 to 22%. In laying hens, MD maggot meal has been reported to replace 50% of FM in a cassava based diet without any adverse effects on FI, FCR, egg production and shell strength. However, 100% replacement was deleterious to hen-egg production (Agunbiade et al., 2007). Mensah et al. (2007) showed that the ducklings fed 11% replacement of MD meal have better growth performances and lower mortality.

The results of these studies showed that MD larvae can be a suitable alternative protein source for broilers, laying hens and duckling.

3.3.- Effect on carcass characteristics and meat quality parameters

3.3.1.- Effect on carcass characteristics

Little studies performed the effect of insect meal on carcass characteristics of broiler chickens. Briefly, Ballitoc and Sun, (2013), observed an improvement in slaughter, dressed carcass and eviscerated weights in broiler chickens fed TM diets with 20 g/kg inclusion level. Similarly, Loponte et al. (2017) reported greater carcass weights in Barbary partridges (Alectoris barbara) fed with HI and TM diets than control group as a partial replacement of soybean meal. On the contrary, carcass traits of broiler chickens and quails were unaffected by dietary MD, TM and HI larva meals inclusion (Cullere et al., 2016; Pieterse et al., 2018; Bovera et al., 2016; Biasato et al., 2017 and 2018).

3.3.2.- Effect on meat quality parameters

Regarding meat quality, the effects of dietary HI larvae meal on meat color are controversial. Cullere et al. (2016) observed that meat redness (a*) in the breast meat of broiler quails was affected by increasing inclusion levels of HI larva meal in diets, showing the highest (1.13) and lowest (0.46) values for 100 g/kg and 150 g/kg HI groups, respectively. On the contrary, Altmann et al. (2018), Pieterse et al. (2018) and Leiber et al. (2017) did not find any significant effect of dietary HI meal on broiler meat color.

The use of MD larva meal in broiler diets has also been associated with a significant decrease in breast muscle lightness (L*) (Pieterse et al., 2014). Differently, Bovera et al. (2016) did not find any significant effect on the color of raw and cooked meat, or on the skin of broiler chickens, also showing that the meat from broilers fed with TM meal could be accepted by consumers.

Even the effects of dietary insect meal on poultry meat proximate composition are conflicting. Cullere et al. (2018) and Pieterse et al. (2018) reported no significant effects on meat chemical composition of broiler quails or chickens fed diets with HI meal, respectively. On the contrary, Ballitoc and Sun (2013), reported the highest percentage of
breast fat content in broiler chickens fed with 100 g/kg level of TM meal inclusion when compared to the groups fed 5, 10 and 20 g/kg TM meal.

3.4.- Effect on gut health

Gut health has been a focus of major research efforts in production animals, since it can be considered a synonymous to animal health and is of vital importance to animal performance (Kogut and Arsenault, 2016).

Gut health depends on the maintenance of the delicate balance between the host, intestinal microbiota, intestinal barrier (in terms of microscopic structure) and dietary compounds (Bailey et al., 2013). Gut microbiota benefits the host by providing nutrients from otherwise poorly utilized dietary substrates and modulating the development and function of the digestive and immune system (Pan and Yu, 2014). Firstly, gut microbiota can affect intestinal morphology through modifications of villus height and crypt depth (Forder et al., 2007), which are considered the main indicators of gut development, health and functionality (Wang and Peng, 2008).

Gut morphology was evaluated by morphometric analysis on duodenum, jejunum and ileum considering villus height, crypt depth and villus height to crypt depth ratio (Biasato et al., 2016, 2017 and 2018; Dabbou et al. 2018). In free range chickens (Biasato et al., 2016) the inclusion of 7.5% dietary TM meal did not affect gut morphology. Similarly, in male (Biasato et al., 2018) and female (Biasato et al., 2017) broiler chickens the dietary inclusion of full fat TM meal (at 5%, 10% or 15% inclusion) did not affect gut morphology or in a limited picture. Dabbou et al. (2018) studied the dietary inclusion of BSF defatted meal (at 5%, 10% or 15% inclusion rate) and found no modification up to 10% dietary inclusion, while at 15% a worsening of gut indexes was observed.

No published studies are available on the effect of insect meal on gut microbiota. Our group (Biasato et al. in press) studied the effect of replacing corn gluten meal by TM meal (as described by Biasato et al., 2016) on the gut microbiota assessment. In comparison with control group, TM birds displayed significant increase and decrease, respectively, of the relative abundances of Firmicutes and Bacteroidetes phyla, with higher Firmicutes:Bacteroidetes ratios (False Discovery Rate [FDR] < 0.05). The relative abundance of Clostridium, Oscillospira, Ruminococcus, Coprococcus and Sutterella genera was higher in TM chickens than C (FDR < 0.05). On the contrary, TM birds displayed significant decrease of the relative abundance of Bacteroides genus compared to the C group (FDR < 0.05).

4.- INSECT FAT IN POULTRY DIET

As mentioned above, research has been mainly addressed to the protein content of insect larvae meals in poultry feeds to replace conventional protein sources. Nevertheless,
insects have different lipid content (ether extract from 5 to 40% of DM) and FA profile related to the species and the rearing substrate (Sánchez-muros et al., 2014; Meneguz et al., 2018). Surendra et al. (2016) and Schiavone et al. (2017a) underlined the importance of defatting larvae meal in order to increase the protein content and the storability of the insect processed meals. Sosa and Fogliano (2017) reported that insect oils (superworm, TM, lesser mealworm, cricket, cockroach) are located between vegetable oils (coiza, linseed, rapeseed, sesame seed, sunflower seed, pumpkin seed, rape low erucic, soybean) and animal origin fats (butter, lard, beef tallow) considering their FA profiles which showed higher SFA contents (mainly C16:0 and C18:0), as well as higher concentrations of MUFA and PUFA. According to EU regulations, there are no prohibitions on the use of insect fats as a raw material for animal compound feeds. In this context, the fat derived from insects (HI, TM and Zophobas morio (ZM)) has been recently and exclusively studied in broiler chicken diets (Schiavone et al., 2017b and 2018; Kierończyk et al., 2018).

Schiavone et al. (2017b and 2018) reported that partial or full replacement of soybean oil with HI fat had no effect on broilers growth performance, carcass characteristics or health. A preference test where broiler chickens were free to choose between diets containing HI fat or soybean oil did not reveal any difference (Schiavone et al., 2017b). Similarly, the use of 5% of TM or ZM fats in total substitution of soybean oil in a 28 d trial did not affect the growth and feed efficiency of broiler chickens (Kierończyk et al., 2018).

Regarding meat quality parameters and FA profile of broiler chickens, Schiavone et al. (2017b) did not find any significant effect on proximate composition, pH and color of HI fat on broiler meat. The authors showed that breast FA profile was greatly affected by partial or total replacement of soybean oil by HI fat inclusion level, in terms of increased SFA and decreased PUFA. This leads to a worsening of the meat nutritional qualities and the authors suggest an effort to improve the FA profile of HI fat modifying the insect larvae rearing substrate, in order to mitigate these negative impacts. Similarly, Kierończyk et al. (2018) showed that only TM oil positively affected the breast meat FA content with a greater amount of PUFA and MUFA contents. Simultaneously, the TM fat lowered the thrombogenic and atherogenic indexes in the breast meat (Kierończyk et al., 2018).

5.- CONCLUSIONS

The poultry sector needs to respond to the growing demand for meat and eggs and enhance its contribution to food security and nutrition. Insect meals could be a solution to future animal protein shortages due to high nutritional and functional value. Recent findings showed that insect meals could be the potential future ingredients for use in the formulation of poultry feeds in partial or total replacement of SBM or FM. No negative effect have been reported on growth performances and eggs quality of poultry fed insect meals with lower inclusion levels. Further research efforts are necessary to deeply
investigate the impact of different insect meal on animal health, safety and meat quality in order to meet society’s approval and European legislation.

6.- REFERENCES


Accessed 10 October 2018.
PAUL, A., FREDERICH, M., MEGIDO, R.A., ALABI, T., MALIK, P.,
Food Agric. doi: 10.1002/jsfa.9261.
PRETORIUS, Q. (2011) The evaluation of larvae of Musca domestica (common house fly)
as protein source for broiler production [MSc. Thesis]. Department of Animal
Science, Stellenbosch University, Stellenbosch, South Africa.
J. Econ. Entomol. 95: 214-220.
Ind. Entomol. 25: 93-98.
8: 85-97.
RUHNKE, I., NORMANT, C., CAMPBELL, D.L.M., IQBAL, Z., LEE, C., HINCH, G.N.
1-11.
SCHIAVONE, A., DE MARCO, M., MARTÍNEZ, S., DABBOU, S., RENNA, M.,
SCHIAVONE, A., CULLERE, M., DE MARCO, M., MENEGUZ, M., BIASATO, I.,
SCHIAVONE, A., DABBOU, S., DE MARCO, M., CULLERE, M., BIASATO, I.,
compelling alternative to fish meal and fish oil. A public comment prepared in
response to a request by the National Marine Fisheries Service. Tifton: University of
Georgia.
V.D.C. (Ed.). InTECH, DOI: 10.5772/67318
SPRANGHERS, T., OTTOBONI, M., KLOOTWIJK, C., OVYN, A., DEBOOSERE, S. et
SPRANGHERS, T., MICHELS, J., VRANCX, J., OVYN, A., ECKHOUT, M., DE
SURENDRRA, K.C., OLIIVIER, R., TOMBERLIN, J.K., JHA, R. and KHANAL, S.K.
SUZUKI, M., FUJIMOTO, W., GOTO, M., MORIMATSU, M., SYUTO, B. and