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Review article

Carcass traits and meat quality properties as affected by nutritional programs and feeding patterns in a rabbit enterprise

Never Assan*
Department of Agriculture Management, Faculty of Science and Technology, Zimbabwe Open University, Zimbabwe

*Corresponding author: neverassan@gmail.com

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ABSTRACT

This review looks at the effects of nutrition on carcass traits and meat quality properties in rabbits. Nutrition is a dominant integral part of a rabbit production enterprise that if appropriately modified will impart acceptable carcass and meat quality attributes sort in new demand market. This implies that feeding an appropriate diet to rabbits is the single most critical component in improving carcass traits and meat quality properties in a rabbit enterprise. Rabbits are instinctively unique in the sense that they have exhibited a relatively pronounced universal taste for common local feedstuffs composed to a greater extent of roughage and agricultural by-products. The utilization of dietary nutrient sources by rabbits is reliant on a variety of complementary determinants that include not only specific energy and protein sources but also intake and digestibility. The high pro health nutritional value and acceptable sensory attributes of rabbit meat have advanced its consumption in several countries and its gaining popularity. Today, when consumer demand for meat are inclined towards consumption of low fat, low calorie and positive healthy meats, new meat sources such as rabbits are increasing their share in the meat markets. Carcass traits and meat quality have shown to positively respond to different dietary nutritional levels and sources in rabbit production. Suitable nutrition regime would improve slaughter weight, hot and cold carcass weight, dressing percentage and the proportion of

valuable giblets. Rabbit fed local unconventional feedstuffs can produce meat with similar or greater amounts of claimable polyunsaturated acids than feeding systems based on feedlot pellets alone. Dietary fats inclusion levels and their sources are important in expressing demanded carcass and meat quality properties, especially on influencing the type of fatty acid composition in meat. Feeding strategies through manipulation of dietary factors should endeavor at increasing the scope of unsaturated fatty acids, while decreasing the portion of objectionable saturated fatty acids promoting pro health value. Future rabbit nutritional research should shift from focusing on promoting quantity to enhancement of quality in response to the new demand market for healthy food in addition to promoting nutritional value and acceptable sensory properties. Heterogeneity in alternative energy and protein sources and their potential replacement value of alternative feedstuff in rabbits' diets should be the targeted outcome from the nutritional research in rabbit meat production.

1. Introduction

Several studies have established that rabbit nutrition has a critical role to play in promoting acceptable carcass and meat quality properties (Hassan et al., 2015; Mista et al., 2012; Stasiak et al., 2010). The developments in rabbit nutritional research has continued to contribute to increasing potential production and meeting the expectations of the health conscious consumers. Rabbit meat has been associated with excellent nutritional value and desirable meat properties which include leanness, low fat content and less saturated fatty acids and cholesterol which have pro-health implications for human nutrition. Appropriate dietary manipulation imparts bioactive substances in rabbit meat known for their agreeable effects on human health (Hernandez, 2008). World over, meat quality perceptions have changed where consumers' concerns are on pro-health properties of meat, sensory attributes, cooking easiness and swiftness, and the cost (Dalle Zotte, 2002) however, this contradict with previous research work which focused on increasing live weight gain and carcass yield. As of late, the dominant meat quality features sort by consumers are color, texture and flavor. It has been demonstrated that dietary manipulation of various ingredients will impart the necessary meat quality attributes to satisfy the new market demand. The development rate of different body tissues and meat quality features can be modified through adequate feeding regime based on synchronizing different protein levels in connection to associated dietary energy levels. Rabbit nutrition studies have substantiated the use of novel feedstuffs to enhance carcass traits and meat quality properties in turn reducing the cost of production (Kaga, 2013; Adam and Haruna, 2002; Xiccato et al., 2002).

However, not all local feedstuffs are satisfactory nutritious sources of energy and protein to adequately support the expected rabbit level of production. In this regard, it calls for intense rabbit nutritional research work to establish which non classical feed sources have acceptable energy and protein replacement values for formulating rabbit diets. The cost of conventional rabbit pellets has been on the increase, which has translated into high price of rabbit meat and their products, unacceptable to the consumer. The focus on non-classical feed resources in an attempt to replace conventional feed ingredients to reduce cost of production is paramount. Dietary supplementation will enhance the contribution of health beneficial bioactive compounds such as conjugated linoleic acid, vitamin E, n-3 fatty acids and selenium (Zhang et al., 2010). Dietary configuration modifies meat composition which in turn is reproduced in the proportion of meat organoleptic properties (Ouhayoun, 1997). This review looks at the effects of nutrition on carcass traits and meat quality properties in rabbits.

2. Nutrition and carcass characteristics

Centoducanti et al. (1990) observed a better carcass yield on 16% dietary crude protein than 18 or 21%. Ashour et al. (2004) evaluating the effects of Yucca schidigera extract on carcass attributes observed that carcass yield and relative organs of kidney and non-edible carcass portions were influenced by dietary supplementation of *Yucca schidigera*. 600mg per kilogram of *Yucca schidigera* supplementation translated to the highest carcass yield and dressing percentage, while 200mg/kg level gave the lowest value. Feeding increases slaughter weight in rabbits which in turn increase offal percent (Butcher et al., 1983). Supplementation of oreganoand rosemary (*Rosmarinus officinalis*) aqueous extract resulted in highest final live weight at slaughter and carcass weight (Cardinal et al., 2015). Rabbits fed with a mixture of non-leguminous and legume forages, supplemented with 30g concentrate produced similar outcome on carcass traits than those fed completely with concentrates. The use of forages in rabbit nutrition had been recommended by Iyeghe-Erakpotobor and Mohammad (2008). The inclusion of wild sunflower leaf blood meal did not affect weight of edible and non-edible carcass portions. This conjecture was corroborated by the results by Adam and Haruna (2002), however, was inconsistence with observation by Collin (1976). In a similar study, Fernandez and Fraga (1996) observed that dressing percentage was not influenced by level of fat in the diet. On the other hand, different levels of diet restriction reduced dressing percentage proportionally (Xiccato, 1999). On contrary, vegetable fat and animal fat enriched diets significantly increased dressing percentage in rabbits (Pla and Cervera, 1997). Working with four rabbits breeds, it was observed that relative to the control diet containing 65% indigenous feedstuff showed an increase in pre-slaughter weight (112g) and hot carcass (89g), while dressing percentage and non-carcass weights were not affected (Al-Dobaib, 2010). Olafadehan (2011) reported pronounced effects of cassava peel based meal on dressing percentage which is in unison with observation by Akinmutimi and Akufo (2006). Balaceanu et al. (2014) working with sunflower oil enriched diets, dressing percentage and meat to bone ratio displayed an improvement depending on supplement level. Diet enriched in vegetable protein by addition of soybean improved meat to bone ration, ascribing to increase in weight of skeletal muscle tissue since bone weight remain constant (Dojana and Savu, 2014). The dressing percentage variation in different studies can be attributable to the influence of other fixed effects such as slaughter weight, age at slaughter and genotype. The dietary structure and composition in terms of essential amino acids affect rabbit meat composition, the rate of growth of animal and correspondingly the slaughter yield (Dojana and Savu, 2014). In contrary, Abdella et al. (1988) reported no significant differences in dressing percentage among rabbits fed 16, 18, or 20% crude protein. Dressing percentage and retail cuts, and physical structure and weights of internal organs were not affected by feed restriction of concentrate in the presence of ad libitum forage feeding. Assessing the effect of dietary supplementation on internal organs Ogunsipe et al. (2014) observed that there was a non-significant influence of rabbits fed sorghum offal based diets on lungs, kidneys, heart and pancreas.

The lowest carcass protein content was observed in rabbits fed high cholesterol diet with no skull root supplementation, however fat content was high. In a similar study Simonova et al. (2010) reported lower protein content and higher fat content in *Musculus longissimus dorsi* of rabbits fed diets supplementation with oregano extract and commercial phyto-additive. Feeding rabbits, a standard diet plus 0.2% oregano (Origanumvulgare) aqueous extract had a higher bone weight than feeding rabbits a standard diet plus 150ppm of vitamin E, this difference was ascribing to increased femur weight, but both diets were more active in suppressing the lipid oxidation of Longissimus dorsi muscle. Attempts are being made by researchers to test the possibilities of inclusion of non-classical protein feed resources in rabbits' nutrition with the view of maximizing profits (Kaga, 2013). Alternative protein feed stuffs are several and diverse depending on agro-ecological regions, hence more research is needed to explore their use as replacement protein sources in rabbit production. However, the dependency on and the need for external supplies of formulated feed will be influenced by the availability of local non classical feed resources and their production economics. Heterogeneity in alternative protein sources and potential replacement value as protein sources in rabbit's diets should be the targeted outcome from the nutritional research in rabbit production.

The pre-slaughter weight, hot and cold carcass weight and dressing percentage differed among rabbits fed different levels of barley grain, where highest values were recorded for 20% barley grain (El-Adawy et al., 2012). Using corn and barley as sources of starch dressing percentage was increased (Xiccato et al., 2002). In a similar study of replacing barley grain by 10% dried barley radical supplemented with enzyme resulted in a higher carcass yield, while the giblets portion varied slightly (Ibrahim et al., 1999). Contrastively, dressing percentage, giblets and

alimentary tract was not influenced by feeding rabbits on diets with different level of barley radical (El-Gendy et al., 2000). The portion of carcass yield or the percentage of edible organs did not differ on three levels (0%, 10% or 15%) of chi *(Salvia hispanica, L)* supplementation. Dietary grape seed extract improved carcass weight, percentage of hot carcass, intestines and edible giblets, while total non-edible carcass portions were reduced (Hassan et al., 2015). Using *Delonixregia* meal diet in growing rabbits Kaga (2013) observed an increase in slaughter weights. Rabbits fed *Delonixregai* at 10% had the highest carcass weight of 496.67g and as the concentration of Delonix increased in the diet the slaughter weights also increase.

It was noted that carcass yield was depressed at higher crude fiber level. This is apparent reasonable and valid considering that higher fiber in a rabbit diet negatively influence digestibility and nutrients utilization. Adewunmi et al. (2000) observed that relative weight of the liver, kidney, heart and spleen in slaughtered rabbits was not affected by source of dietary fiber. Diets did not have an effect on meat and bone ratio and on relative organ weights (Oteku and Igene, 2006). High dietary fiber provided in the last week of the fattening period had a positive influence on gastrointestinal tract weight, chilled carcass weight and cut yield in rabbits. Moderate fiber enriched diet (14% full fiber content) improved dressing percentage while 23 or 33% fiber enriched diets led to a decreased on the dressing percentage (Dojana and Savu, 2014). Xiccato (1999) commented on the increase of dietary fiber intake which is comparable to restricted feeding, which result in presses energy digestibility, restrict growth and a decline in dressing percentage. Ripe plantain and yam peels and cassava peel diets positively influenced the variation in prime cuts of growing weaner rabbits (Idowu et al., 2006). However, for meat to bone ratio ensiled cassava peel had the least values compared with sun dried cassava peel meal and retted cassava peel meal. Palm press fiber based diets fed to rabbits enhanced productivity and carcass quality in addition to improving animal's health (Houndonougbo et al., 2012).

3. Nutrition and meat quality properties

World over, meat quality is very emotional and dynamic notion, and the consumer perception of meat quality has been modified over the years. Currently, meat consumers have subjectively changed the meat quality concept which has forced rabbit meat producers to take cognizance of the paradigm shift through producing acceptable meat quality for the new market demands, beliefs and appetite. Novel factors such as meat safety and health are becoming dominant credence quality properties. These new elements are associated with environmentally friendly production systems, where rabbit nutrition could play a major role. Ouhayoun (1989) pointed out that feeding has always been regarded as a valuable variation factor in determining meat quality properties. In line with the influence of feeding on meet quality in rabbits Corino et al. (2003) observed that sensory properties are determined by the nature of dietary provision, apart from other variability factors. The other credence quality properties of color, texture and flavor pose as the major attributes that affect consumer acceptance of meat. Peroxidation of lipids has been implicated as the leading agent of quality deterioration in meat and meat products (Addis, 1986).

Evaluating the effects of different levels of vegetable fiber (wheat straw) diet on quality of rabbit carcass and meat quality moderate supplementation of the fiber percentage in the rabbit diets increased the percentage of dissectible fat and the meat to bone ratio, but at 23% fiber diet inclusion resulted in decreased dressing percentage, dissectible fat and the meat to bone ratio. It has been noted that dietary fiber supplementation levels influence carcass yield by both decreasing muscle mass and by depressed amount of fat in rabbit carcass (Dojane et al., 2011).

Dietary fat composition meant to be fed to rabbits can be manipulated as proven by many studies (Dalle Zotte, 2002; Hernandez and Gondret, 2006). Dietary *Amaranthus dubius* as an alternative feedstuff in rabbits, increased protein and fat contents, while moisture content of meat decreased proportionally (Molina et al., 2017). In the same study, drip loss percentage, dissectible fat percentage and thoracic cage increased with increase in the proportion of *Amaranthus dubius* in the diet. 32% was suggested as an acceptable proportion of substituting conventional ingredients for *Amaranthus dubius* without compromising carcass and meat quality. Humic fatty acid dietary preparation had a beneficial effect on the meat quality properties which include iron levels, hardness and pigmentation, despite the susceptibility of fat to oxidative changes (Mista et al., 2012). Dietary fat inclusion level and source play a major role in carcass and meat quality outcome. When fat is incorporated in the diet the fat content of the meat increases while the protein content decreases (Dalle Zotte, 2002). Therefore, it is important to know at what level the fat should be incorporated. There is a tendency of depressed digestibility and nutrient

unavailability when high levels of fat are included in the diet. Dissectible carcass fat was higher in rabbits fed sunflower oil enriched diet. The final pH was low with improved sensory properties. Feeding different levels of sunflower oil enriched diets displayed a positive impact on carcass characteristic and some sensory properties as a result of increased carcass dissectible fat and enhanced overall meat fat content (Balaceaunu et al., 2014).

Simonova et al. (2010) and Stasiak et al. (2010) showed the effect of diet as it influences pH, which is a major factor of control on meat quality attributes. pH has been cited as one of the most important meat parameters that influence meat quality after slaughter (Aksu et al., 2005). Esenbuga et al. (2008) reported a positive effect of dietary humate supplementation of decreasing meat pH. Maj et al. (2008) proclaimed that for meat of acceptable quality the pH should be in the range of 5.4 to 5.8 after 24 hours of meat storage. pH influence changes in protein structure likewise water holding capacity and sensorial attributes primarily color and tenderness. However, the pH appears to depend on the portion of the carcass (Szkucik and Puz-Lukasik, 2006). The pH value relies upon the proportion of muscle energy metabolism and represents an essential role in sustaining meat quality during storage. Low pH value determines microbial environmental balance due to bacteriostatic effects on meat (Dalle Zotte, 2002). Meat dryness increases when pH decreases because the muscle protein are closer to the iso-electric point consequently lower meat hydration (Dalle Zotte, 1995). This implies that meat pH will influence water holding capacity. Decline in pH value is very important as it inhibits growth of bacteria, rates of conversion of color and formation of undesirable rabbits' meat flavors. Plant polyphenols from canola meal fed to growing rabbits were convincing in reducing pH value during storage of rabbit meat (Olorunsanya et al., 2007). Virag et al. (2012) observed that high level of vitamin E compared to the low level significantly increased with low pH. Higher meat pH values were observed in rabbits fed animal fat or vegetable enriched diets, inconsiderate of muscle weight that was measured (Pla and Cervera, 1997). The pH values disparities in various studies may be due to differences in pre-slaughter handling than dietary, that probably resulted in variation in glycogen reserve before slaughtering (Oteku and Igene, 2006). Meat lightness increases with the activity of muscle myofibrillar protein shrinkage, which is itself is negatively associated with pH value i.e. the lower the pH value the higher lightness (Dalle Zotte and Ouhayoun, 1998). In another study Polak et al. (2006) confirmed a positive relationship between pH and red color of meat. Feeding regime comparing rabbits fed ad libitum and on a restricted (85-90% of the ad libitum diet) feed intake levels influenced all meat quality parameters except value of meat color (Metzger et al., 2011).

Conformation of fatty acids in rabbit meat can be easily modified by control of dietary nutrient sources (Decker and Park, 2010). The content, composition and quality of dietary fat can affect the meat fatty acid profiles and their sensitivity to lipid peroxidation (Song et al., 2001). It has been acknowledged in various studies that supplementation is effective in improving the n-3 PUFA content, decreasing the n-6/n-3 ratio in turn reducing the saturation, atherogenic and thrombogenic indexes of the meat and fat (Coorey et al., 2015; Peiretti, 2012; Peiretti and Meineri, 2008; Wood et al., 1999). High PUFA, notably amount of high oleic or linolenic acid in rabbit pelleted diets were observed to alter rabbit meat fatty acids profiles in turn decreasing the n-6/n-3 ratio (Corino et al., 2007; Bianchi et al., 2006; Dal Bosso et al., 2004) and this resulted in increasing unsaturation index (Lopez-Botre et al., 1997). Szendro (2010) proclaimed that dietary modification has an effect on increasing levels of essential fatty acids, vitamin E and selenium in rabbit meat. This process may result in improved nutritional quality of rabbit meat for consumers. Rabbit diets have great repercussion on the fatty acids profiles or composition of rabbit meat which entails that there is a potential of manipulation of the dietary composition to promote beneficial fatty acids profiles in rabbit meat. Hernandez and Zotte (2010) has confirmed the effects of diet composition on the lipid profile of rabbit meat. This drive has led to a keen interest by other researchers in dietary modification that effectively contribute to the reinforcement of the nutritional value of rabbit meat. However, the success of utilization of different fat sources to manipulate fatty acid profiles in rabbit meat production exhibit relatively pronounced diversity in outcome and seems dependent on a complex myriad inter-related factors. Rabbits are characteristically unique in the sense that they are able to directly incorporate dietary fatty acids into their adipose tissue and intramuscular tissue lipids, this making it possible to modify the fatty acids profile of rabbit meat through the strategic use of unsaturated dietary fat sources (Zotte, 2002). It has been reported recently that the deposition of polyunsaturated fatty acids in rabbits' tissues increases as the amount of chia *(Salvia hispanica, L)* increased in the diet without adverse effects on animal performance (Coorey et al., 2015; Peiretti, 2012). Previously, Peiretti and Meineri (2008) feeding chi seeds to growing rabbits the proportion of PUFA levels in the *longissimus dorsi* muscle and perirenal fat was significantly elevated with increasing in chi seed diet supplementation, while the unacceptable saturated fat acids decreased. As a direct outcome of dietary effect, feeding of Spirulina platensis to replace soybean and alfalfa at different levels, the content of fatty acids increased

in the perirenal fat and meat as a result of increasing Spirulina platensis supplementation. In the same study, in addition to alteration of fatty acids profile in the perirenal fat, the athoregenic and thrombogenic indicator of the rabbits' tissue showed significant differences (Peiretti and Meineri, 2011). Palazzo et al. (2015) working with dietary natural extracts from *Lippi citriodora* reported that the supplement changed the fatty acids profiles of meat with a decrease in unacceptable saturated fatty acids and a boost in pro healthy polyunsaturated fatty acids compared to conventional pelleted diets. High dosage of *Lippi citriodora* natural extract had a positive influence on meat tenderness and juiciness. This highlighted a better consistency as compared with rabbits fed conventional pelleted diet and low natural extract. In a similar study, Capra et al. (2013) evaluating meat quality properties using diets with or without fresh alfalfa ad libitum observed a favorable change in fat composition which had a significant increase in the content of linolenic acid C18:1n-3. The increase in n-3 in turn improved the n-6/n-3 ratio, which is a positive sign for health conscious consumer. This reflects the current thrust on rabbit nutrition research focused on enhancing the content of n-3 polyunsaturated fatty acids and improving the n-6/n-3 ratio (Tres et al., 2008). Working with growing rabbits, Martinez et al. (2005) observed that the n-6/n-3 ratio was higher in rabbits fed mulberry supplementation than those fed Lucerne. However, the proportion of protein in meat was the same for rabbits fed mulberry or Lucerne, had learner carcass and a little more moisture. This is plausible reason to suggests that mulberry is a potential alternative feedstuff with the capacity to support meat production for human consumption. Fatty acids content differs considerably dependent on the disposition of the diet hence research focusing on increasing the n-3 PUFA content in rabbit meat through dietary provision is feasible (Peiretti, 2012). Dietary supplementation with linseed oil plus selenium in growing rabbits had a positive effect on the composition of lipid meat fraction due to high concentration of unsaturated fatty acids and decreasing saturated fatty acid content (Fernandez and Fraga, 1996). This could be partly explained by the fact that higher fat content of the rabbit meat could be an alternative of the use of different fat sources (fats from plants or animals) (Petracci and Cavani, 2012).

The recent focus on rabbit meat science research is the modification or alteration of nutritional profiles through promoting the content of desirable polyunsaturated fatty acids and increase the oxidative stability activities through supplementation of natural oxidants to impart appropriate meat pigmentation and minimize lipid oxidation in meat. Fatty acids profiles play a crucial part in defining meat quality due to its influence on sensory attributes and its implication for nutritional value of rabbit meat for human consumption. The differential fatty acid composition has complete effects on meat quality because fatty acids composition regulates firmness of adipose tissue and oxidative stability of muscle, later affecting flavor and pigmentation. It has been widely recognized that high PUFA levels may influence meat flavor due to sensitivity to oxidation and the yielding of unpleasant volatile compounds during cooking (Wood et al., 1999). This implies that increasing the content of PUFA there is a higher rate of oxidation. Lipid oxidation is a dominant obstacle in rabbit meat production due to the high content of polyunsaturated fatty acids, which can lead to oxidation, which reduces the shelf life as a result of rancidity and unacceptable color changes (Abdalla, 1999; Engberg et al., 1996). Addis et al. (1996) supported the notion that the presence of substantial levels of unsaturated lipids in muscle resulted in an increased rate of oxidation deterioration which have a negative human health implication (Addis et al., 1996). It has been noted that mono-unsaturated fatty acids and poly-unsaturated fatty acids (PUFA) in particular long chain n-3 PUFA have health benefits on consumers (Wood et al., 2003).

Rabbit meat and its products lipid oxidation might lessen its stability, reduce nutritional value and in turn deterioration of sensory properties which impact negatively on meat quality (Gray et al., 1996). Lipid oxidation has an adverse effect of reduced nutritional value and organoleptic, which compromises the utilization of essential amino acids, fatty acids and the lipid soluble vitamins A, D, E and K, while caloric value decreases. Off flavors, color transformation such as darkening of fats and oils and development of lightening pigmentation, likewise pronounced flavor loss are some of the result of lipids oxidation in rabbit meat (Arab-Tehrany et al., 2012). Since PUFA are highly susceptible to oxidation, it is necessary to safeguard meat and its products from lipid oxidation through dietary inclusion of various natural antioxidants (Trebusak et al., 2011). The PUFA content of phospholipids was positively associated with the development of rancidity (Igene et al., 1980). Lipid (PUFA) oxidation is a highly deteriorative process resulting in production of biochemical products which are originator off flavors (Let et al., 2005). Susceptibility of polyunsaturated fatty acids to lipid oxidation result in many complications that is generally associated with reduced shelf life, unacceptability of meat by consumers, functionality, compromised nutritional value and food safety (Arab-Tehrany et al., 2012). It is imperative to add dietary antioxidants to rabbits feed containing fats rich in unsaturated fatty acids (Kowalska and Bielanski, 2009) to

maintain nutritional value and improve acceptability of rabbit meat. Prevention of lipid oxidation in muscle based food can be achieved by the addition of antioxidants. Organic antioxidants extracts from natural sources have been used to safeguard meat against oxidation (Weuk, 2003). This is on the premise that use of antioxidants can prolong shelf life and increase acceptability of meat by consumers. Supplementing rabbit's diets with acceptable amounts of vitamin E (Corino et al., 1999) and C (Lofiegoet et al., 2004) seemed to effectively impede the oxidative processes and enhance lipid stability of rabbit meat storage. Antioxidants are thought to quench free radicals and include the endogenous enzymes such as selenium dependent glutathione peroxidase, copper-zinc dependent superoxide dismutase and dietary antioxidants such as vitamin C, E, Zinc and phenolic compounds (Munisa et al., 2015). In a similar study the effectiveness of oregano essential oil dietary inclusion applied a significant anti-oxidative reaction on rabbit meat at the level of 200gmg/kg. Total antioxidant capacity in rabbits' blood were increased by adding dietary grape seed extract (Hassan et al., 2015). Supplementation with canola meal fed at 10% level improved the amino acid profile enhancing the nutritional quality and meat stability (El-Medany and El-Reffaei, 2015). This was attributable to the presence of appreciable amount of phenolic and antioxidants in canola meal. The canola meal provided natural bioactive material in turn improving the meat nutritional status by decreasing oxidation of lipids. The increase of PUFA content produced as a result of utilization of linseed supplementation could lead to meat oxidation, which in turn reduce shelf life of rabbit meat (Manahan, 2000). The supplementation of rabbit diets with non-conventional feedstuffs, false flax seed (Camelinasativa) (Peiretti et al., 2007), or chia (*Salvia hispanica, L*) (Peiretti and Meineri, 2008) have been successful in increasing PUFA content and reducing the n-6/n-3 ratio as expected, without having an adverse effect on carcass traits. Omoikhoje et al. (2008) observed a non-significant effects of feeding cassava roots meal based diets on the organoleptic properties on rabbit meat. The differential oxidative capacity in different nutritional research studies may be attributed to mode of different oxidative mechanisms of action and type of oxidant used (Simitzis et al., 2014). On the other hand, oxidation and glycolytic muscles or adipose tissue are different in their sensitivity towards peroxidation (Vigrag et al., 2008).

Rabbits fed sunflower oil enriched diets improved aroma, intensity and quality and juiciness but had no effect on tenderness, taste intensity, taste quality and overall sensory attributes (Balaceanu et al., 2014). The replacement of maize with cassava waste meal in rabbit diet did not influence dressed carcass weight, carcass length, percentage muscle and bone ration, however the water holding capacity of rabbit meat was improved (Olorunsanya et al., 2007). Kowalska and Bielanski (2009) reported that tenderness and juiciness were improved in rabbit meat supplemented on 30% fish oil. This supports the observation by Dal Bosco et al. (2004) on tenderness and acceptability, obtained higher values on tenderness when rabbits were supplemented with flax seed and tocopherol acetate. Talukder (2013) emphasized the importance of meat tenderness and juiciness as the factors which influence acceptability of rabbit meat. Rabbit meat has been associated with pleasant sensory characteristics expressed by tenderness, leanness and delightful flavor (Gasperlin et al., 2006). Simonova et al. (2015) supplementing rabbits with the controversial probiotic strain *E faecium* and bacteriocinogenic the mineral quality of meat was improved. On the other hand, pH, color, water holding capacity, protein and fat content or energetic value of the carcass were not negatively affected. 2% of oregano replacement in a standard diet had a positive effect on carcass and meat quality properties in rabbits (Cardinali et al., 2015).

4. Implication

Currently, not only the rabbit carcass yield, but also the credence meat quality attributes has become more and more crucial. This new market demand emanates from the increased awareness of consumers on special pro healthy meat properties. In order to maintain high rabbit meat nutritional value and appropriate sensory attributes producers should focus on dietary energy and protein manipulation. Dietary modification has been identified as a major source of effectively enhancing the essential fatty acids profiles and other nutrients in rabbits' meat. Due to the rising prices of commercial feed in rabbit production it is imperative to utilize non-classical feed resources in rabbit diets formulation which result in cutting down the cost of production and in turn maximizing profits. Use of alternative feedstuffs should be preceded by careful and accurate nutritional research in identification of the appropriate and relatively cheap energy and protein alternative feedstuffs sources based on their replacement value to conventional feedstuffs. However, the aim of feeding alternative feedstuffs is to reduce cost of production but should not compromise on carcass traits and meat quality attributes. It appears that the previous rabbit nutrition studies across the globe point to the fact that there is a diversity of vegetable, forages and aquatic plants

that can be used effectively in rabbit diet formulation as partial substitutes to replace or in combination with energy or protein sources from conventional feed ingredients.

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