ONLINE JOURNAL OF ANIMAL AND FEED RESEARCH

An International Peer-Reviewed Journal which Publishes in Electronic Format

Volume 8, Issue 3, May 2018

Online J. Anim. Feed Res., 8 (3): May 25, 2018

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Volume 8 (3); 25 May 2018

Research Paper

Effect of using lemon citrus compared to rennet coagulation on physiochemical yield and sensory properties of cheese from cow and goat's milk.

Bhagiel BI, Hamid EE and Hamza AE.

Online J. Anim. Feed Res., 8(3): 46-51, 2018; pii: S222877011800007-8

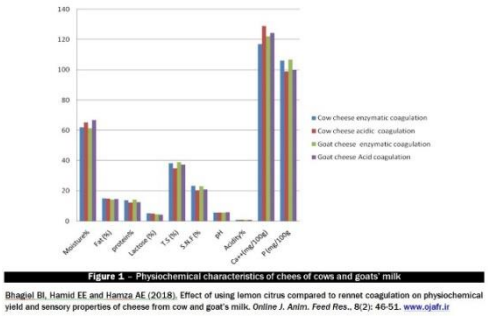

Figure 1 - Physiochemical characteristics of chees of cows and goats' milk

Bhagiel BI, Hamid EE and Hamza AE (2018). Effect of using lemon citrus compared to rennet coagulation on physiochemical yield and sensory properties of cheese from cow and goat's milk. *Online J. Anim. Feed Res.*, 8(2): 46-51. www.ojafr.ir

Abstract

This study was conducted to assess the yield and sensory characteristics of cheese produced from different milk sources (cow and goat using lemon citrus juice as coagulant compared with the commonly used rennet enzyme. The milk of the two species was collected from experimental dairy farms of animal production college (Kuku) and college of agricultural studies (Shambat), Sudan university of science and technology. After pasteurization at 85 ºC for 30 min and cooling to 40 ºC, the collected milk samples were divided into four groups (each five liters of goats' milk and cow's milk were treated with both Rennet enzyme and citric acid (Lemmon juice), respectively. Thereafter, the samples were incubated at 38 ºC. The results revealed that Cow's and goat's milk that treated by rennet enzyme coagulated after one hour of incubation, while both milks treated by citric acid was coagulated immediately after 10 min. Significant differences ($P \leq 0.05$) on physiochemical characteristics (protein, fat, total solids or TS, acidity, ash, lactose and solids-not-fat or SNF) between goat's and cow's cheeses were obtained. It was observed that cheese manufactured from goat's milk using citric acid aggulation recorded higher protein, fat, ash, T.S, pH and TNF, percentages, while acidic cow's cheese showed high moisture, lactose, and acidity. While, enzymatic goat's cheese revealed high percentages, of protein, fat, ash, TS, Ca and acidity, and enzymatic cow's cheese revealed high moisture, lactose, SNF and Phosphorus percentage. The sensory evaluations showed significant ($P \leq 0.05$) differences on taste, flavor, smell, texture, and overall acceptability. The best values for taste, color and overall acceptability were obtained from enzymatic (rennet) goat's cheese followed by enzymatic (rennet) cow's cheese, then acidic (citric) cow's cheese and acidic (citric) goat's cheese was the last. The perfect hardness and texture were obtained from enzymatic (rennet) cow's cheese. Moreover, the best smell was recorded for the cheese produced from cows' milk by enzymatic curdling. Where, the most acceptable flavor was attained by the cheese processed from cows' milk by citric acid coagulation. The results indicated that the weight of the final products obtained from cows' and goats' milk using citric acid coagulant was higher than that obtained from the same milks using rennet enzyme coagulant. It is possible to conclude that lemon citrus juice can be utilized as an alternative coagulant in production of local Sudanese white cheese for high yield and short curdling time which performed favourably with the commonly used rennet enzyme.

Keywords: Lemon Juice, Rennet, Coagulation Cheese Processing, Cows, Goats, Milk

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Research Paper

Challenges and market opportunities of cattle fattening around Gondar town, Ethiopia.

Birhan M, Adane K, Abebe Z And Habtie B.

Online J. Anim. Feed Res., 8(3): 52-58, 2018; pii: S222877011800008-8

Abstract

A study was conducted to assess cattle fattening opportunity, challenges and marketing system from January to May, 2017. The primary data was collected from purposively by interview in selected 50 cattle fattener households. According to the respondents, information color was the major selection criteria for fattening purpose with the proportion of 28% red coat and 10% for bulla (mixed color), 8% for white and 44% for black colors, whereas castration of animals was another fattening criterion for in the study area. Accordingly, about 6% of the respondents were fattened the castrated animals while the remaining 94% were the uncast rated bulls. Almost all respondents indicated that concentrate (10%), roughage (8%) and both concentrated and roughage feeds (82%) were the used feed sources for fattening purpose. Deciding finishing period of fattening cattle in the study area were based on live weight change (58%), by calculating feeding length (4%) and 38% of the respondents were used both. Market information is a crucial issue to reduce information gaps and uncertainties that existed in the livestock sector. The price of fattening cattle depends on weight and age of the animals. Lack of capital (40%) was the main constraint to begin cattle fattening and other constraints were shortage of feed and water, insufficient land, occurrence of disease and lack of awareness in order of importance 26.67%, 16.67%, 10%, 6.67%, respectively. And the opportunity of the area is also livestock access, meat demand of people increase and butchers house. Therefore, from the present study, it can be concluded that cattle fattening in Gondar town is one of the potential strategy to improve the livelihood of the family and had a good potential of market flow.

Keywords: Cattle Fattening, Constraint, Opportunity, Challenges, Opportunity

[Full text-PDF] [XML]

Research Paper

Maize cobs and potato hash silage as alternative feed for grower pigs under smallholder production in Gauteng province of South Africa.

Thomas RS, Ncobela C, Mphofu K, Sebothoma P, Tsatsimpe M, Makgoth OGi, and Kanengoni AT.

Online J. Anim. Feed Res., 8(3): , 2018; pii: S222877011800009-8

Abstract

Maize cobs (MaC) and potato hash (PoH) are readily available and can be incorporated into pig diets to reduce feed costs and minimize nutrient losses to the environment but there is scant information on their utility on farm. A study was designed to evaluate pigs' growth performances when fed three diets; a control diet (CON) and a diet containing maize cob and potato hash silage inoculated with an exogenous feed enzyme (xylanase (Natugrain TS L®)) (MaCPoHES) and (MaCPoHS) without an exogenous feed enzyme on-farm level. The study was conducted at two smallholder pig farms in Gauteng province, South Africa. The three diets were formulated to contain 16 % crude protein (CP)/kg DM (dry matter) and 14 MJ of digestible energy (DE)/kg DM. Sixty large white x landrace cross bred pigs (30±5.0 kg body mass) from each farm were randomly allocated to the three treatment diets in a completely randomized design and fed ad libitum for 56 days. The pigs that were fed MaCPoHES from both farms had a better feed conversion ratio (FCR) compared with pigs that were fed CON and MaCPoHS. In addition, pigs that were fed CON had higher dry matter intake (DMI) than pigs that were fed MaCPoHS diets. There were treatment x farm interactions for average daily gain (ADG) and FCR. In addition, there were no treatment x farm interactions for initial weight (IW), final weight (FW), average daily feed intake (ADFI) and dry matter intake (DMI) in both farms. However, pigs at Zuurbekom farm had a higher ADG, ADFI and DMI than pigs at Winterveld farm. Pigs fed MaCPoHES diet had a better FCR compared to the CON on both farms. This suggests that the use of these agricultural by-products in growing pig diets can help reduce feed costs. More studies need to be carried out to determine the optimum inclusion level of MCPH in pig diets, their impact on carcass quality and the cost benefit.

Keywords: Smallholder farm, Maize cob, Potato hash, Enzyme, Grower pigs

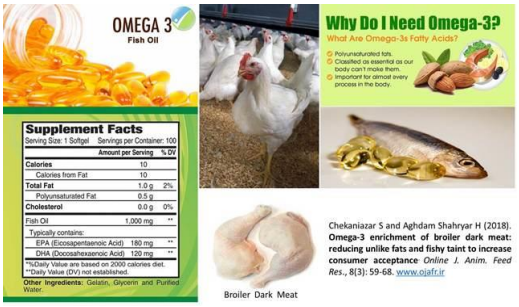
[Full text-PDF]

Research Paper

Omega-3 enrichment of broiler dark meat: reducing unlike fats and fishy taint to increase consumer acceptance

Chekaniazar S and Aghdam Shahryar H

Online J. Anim. Feed Res., 8(3): 74-83, 2018; pii: S222877011800010-8



Abstract

Fish oil (FO) rich in the long chain n-3 polyunsaturated fatty acid (LC n-3 PUFAs) such as eicosapentaenoic acid (EPA, C22:5 n-3) and docosahexaenoic acid (DHA, C22:6 n-3) play substantial roles to improve FA composition and enhance health-related effects of animal products like meat, dairy and eggs. However, optimization based solely on omega-3 enrichment could lead to undesirable odours in animal-source foods, unless the FO withdrawal period is applied for 1 week before slaughter. The aim of study was to investigate whether the replacement of FO with poultry fat (PF) in the diet for 21 days followed by its withdrawal for 1 week affected fishy taint of thigh meat, cholesterol (CHOL) and triglycerides (TG) concentrations, n-3-enrichment and growth rate of male broiler chickens. Two hundred and forty birds (21-day-old, Ross 308) were fed 1 of 4 dietary groups (T1=3%PF, T2=2%PF+1%FO, T3=1%PF+2%FO, T4=3%FO) during a 21-d growth period. Broilers fed dietary fish oil indicated an improved rate of growth ($P < 0.01$) plus a decline of the CHOL and TG levels as well as the n-6: n-3 ratio in thigh meat. Moreover, amount of LC n-3 PUFAs especially EPA and DHA were increased and hence a lower monounsaturated FA: PUFA ratio was detected on day 42 and also after oil/fat withdrawal from the diet. The juiciness and tenderness of dark meat of broilers fed FO dietary groups were raised. But the fishy taint was unfavorably higher ($P < 0.01$) especially in T4 meat that affected flavor and acceptability thereof. The dissatisfaction of the panelists toward cooked samples of T4 scored as neither like acceptable and their satisfaction with group 3 meats scored as good. Since the lowest n-6/n-3 FAs and a good growth rate were also observed for 1%PF+2%FO (T3), group 3 meats were selected as good-quality omega-3 enriched broiler meat. It is concluded that pre-slaughter withdrawal of replaced fish oil in broiler diet seems ensure the good performance, n-3 enrichment of thigh without probable off-flavors or unlike fats (CHOL and TG) of dark meat.

Keywords: Broilers, Fish Oil, Fatty Acids, Cholesterol, Thigh Meat, Sensory Quality

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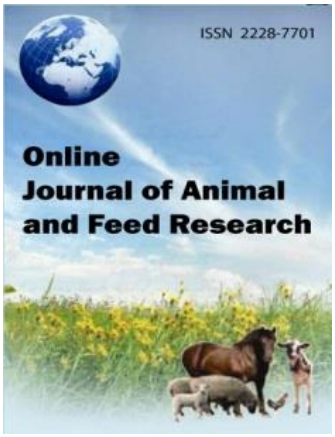

ISSN: 2228-7701

Frequency: Bimonthly

Current Issue: 2018, Vol: 8, Issue: 3 (May)

Publisher: SCIENCELINE

Online Journal of Animal and Feed Research is an international peer-reviewed journal, publishes the full text of original scientific researches, reviews, and case reports in all fields of animal and feed sciences, bimonthly and freely on the ınternet ...view full aims and scope

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2018 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 8, Issue 3: 46-51; May 25, 2018

ISSN 2228-7701

EFFECT OF USING LEMON CITRUS COMPARED TO RENNET COAGULATION ON PHYSIOCHEMICAL YIELD AND SENSORY PROPERTIES OF CHEESE FROM COW'S MILK AND GOAT'S MILK

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ABSTRACT: This study was conducted to assess the yield and sensory characteristics of cheese produced from different milk sources (cow and goat using lemon citrus juice as coagulant compared with the commonly used rennet enzyme. The milk of the two species was collected from experimental dairy farms of animal production college (Kuku) and college of agricultural studies (Shambat), Sudan university of science and technology. After pasteurization at 85 ºC for 30 min and cooling to 40 ºC, the collected milk samples were divided into four groups (each five liters of goats' milk and cow's milk were treated with both Rennet enzyme and citric acid (Lemmon juice), respectively. Thereafter, the samples were incubated at 38 ºC. The results revealed that Cow's and goat's milk that treated by rennet enzyme coagulated after one hour of incubation, while both milks treated by citric acid was coagulated immediately after 10 min. Significant differences (P≤0.05) on physiochemical characteristics (protein, fat, total solids or TS, acidity, ash, lactose and solids-not-fat or SNF) between goat's and cow's cheeses were obtained. It was observed that cheese manufactured from goat's milk using citric acid aggulation recorded higher protein, fat, ash, T.S, pH and TNF, percentages, while acidic cow's cheese showed high moisture, lactose, and acidity. While, enzymatic goat's cheese revealed high percentages, of protein, fat, ash, TS, Ca and acidity, and enzymatic cow's cheese revealed high moisture, lactose, SNF and Phosphorus percentage. The sensory evaluations showed significant (P≤0.05) differences on taste, flavor, smell, texture, and overall acceptability. The best values for taste, color and overall acceptability were obtained from enzymatic (rennet) goat's cheese followed by enzymatic (rennet) cow's cheese, then acidic (citric) cow's cheese and acidic (citric) goat's cheese was the last. The perfect hardness and texture were obtained from enzymatic (rennet) cow's cheese. Moreover, the best smell was recorded for the cheese produced from cows' milk by enzymatic curdling. Where, the most acceptable flavor was attained by the cheese processed from cows' milk by citric acid coagulation. The results indicated that the weight of the final products obtained from cows' and goats' milk using citric acid coagulant was higher than that obtained from the same milks using rennet enzyme coagulant. It is possible to conclude that lemon citrus juice can be utilized as an alternative coagulant in production of local Sudanese white cheese for high yield and short curdling time which performed favourably with the commonly used rennet enzyme.

Keywords: Lemon Juice, Rennet, Coagulation Cheese Processing, Cows, Goats, Milk

ORIGINAL ARTICLE
pii: S2228770118000078
Received 18 Jan. 2018
Accepted 06 Apr. 2018

INTRODUCTION

Almost one third of the world's milk production is used in cheese manufacture, where the manufacture of cheese is considered a sort of milk preservation. Moreover, cheese is highly nutritious food with many diverse flavors and textures, which can use as a snack or as a part of dish or prepackaged convenience food (Quinee, 2004). Cheese is a widely consumed product by the general population; it is highly-concentrated, rich in proteins and lipids, essential amino acids, and minerals such as calcium and phosphorus (María et al., 2017).

In order to extend the shelf-life, quality of fresh milk and provide the consumer product with good flavor and high nutritive value, the process of cheese making has been adopted widely. The first step in cheese processing is the coagulation of raw milk in which κ-caseinolytic enzymes contribute to micelle aggregation. The common coagulant used is animal rennet, which has been the traditional coagulant in cheese manufacture for several years,

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(Ahmed et al., 2009). However, coagulation determines the yield, quality and final cheese properties (Akinloye and Adewumi, 2014). The individual characteristics of each cheese variety are due to the type of milk, microbial starter culture and the manufacturing procedure used (Ahmed, 1997). Recently, utilization of coagulants of plant origin in cheese processing has been found an increased interest because of several reasons such as religious consideration, nutritional behavior (vegetarianism) and sometimes for healthy risks (some countries forbid the use of genetically modified calf rennet (Roseiro et al., 2003). It has been reported that there are several commercial plant proteases (enzymes), such as bromelain and papain, used as coagulant in cheese manufacturing (Murata et al., 1987). In some European countries (Spain and Portugal) *Cynara sp*. is used as a plant coagulant in manufacturing cheeses from sheep and goats milk (Tejada et al., 2008). In Nigeria and many parts of West Africa, the traditional cheese makers use Sodom apple, (Calotropis procera) extract for clotting milk (Aworth and Muller, 1987). Extracts from pineapple, Banincasa cerifera and solanum toruum were use in Cheddar cheese making.

Plant extracts are characterized by high ability to hydrolyse the κ-casein, leading to curd formation, and they are also containing main enzymes responsible for β-casein hydrolysis (Roseiro et al., 2003). It is well known that lemon (*citrus limon)* juice is used in cheese manufacturing for fast coagulation property and high availability with a low price. For this purpose; the present work was initiated to evaluate the effect of lemon (citrus limon) juice as coagulant on physicochemical properties of cheese processed from milk of Sudanese cows and sheep compared with rennet enzyme.

MATERIALS AND METHODS

Milk test (basic properties of milk)

High quality fresh cow and goat milk was obtained from the experimental farm of animal production department, Agricultural college animal production, University of Sudan for science and technology; north Bahari, Khartoum then transferred to the laboratory of the same department where the whole experiment was conducted. The major investigated tests in milks of cows and sheep were fat (determined by Gerber method according Bradly et al., 1992), protein, (determined by Kjeldahl method according to AOAC, 1990) total solids (determined according to the modified method of AOAC 1990), solids not fat (was determined from the following equation:

SNF (%) = %TS - % fat

Also, ash content was determined according to (AOAC, 1990) in addition to the pH (using digital pH meter) and Titeratable acidity, (determined according to AOAC, 1990).

Coagulants

Rennet. Rennet (HR.HANSEN coagulant stick 50ltr, of milk), was obtained from veterinary pharmacy.

Preparation of lemon juice. Lemon fruits were purchased from local market; the fruits were cut and then squeezed into a clean bowl. The extracted content was sieved, measured with measuring cylinder and thoroughly mixed with equal volume of fresh clean water.

Cheese processing

Twenty liters of raw cows and goats milk were used to manufacture cheese from milk of the above species using both rennet and lemon juice as coagulants to compare physiochemical properties of cheese produced from the two milks. Milk quantity was divided into four patches each 5 liters, (each patch was coagulated by both rennet and lemon juice). The following illustration shows cheese processing steps:

Raw milk was pasteurized at (85 C for 30 minutes)
↳ **Cooling down the milk in iced water to 45 C**
↳ **Addition of coagulants and stirring** [Rennet (0.1dissolved in water) and lemon juice (in a separated experiment)]
↳ **Adding salts** [Addition of Na Cl (180 gm (w/w) and 0.5% of calcium chloride (w/w)].
↳ **Clotting (occurred in 30 minutes) and Whey drainage**
↳ **Weigh fresh cheese to determine yield**

Determination of cheese yield

The final product of the white cheese from the species milks was weighted after three days of manufacturing and the yield of every replicate recorded by using sensitive balance. The final weight was determined by the following equation:

$$\% \text{ of cheese yield} = \frac{\text{Grams of cheese produced} \times 100}{\text{Grams of milk used}}$$

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Sensory evaluation

Ten postgraduate students were randomly selected to evaluate cheese sensory characteristics that include taste, color, flavor, texture and overall acceptability.

Statistical analysis

The data were analyzed using (ANOVA) completely randomized design. Mean separation was done using Duncan's multiple range test.

RESULTS AND DISCUSSION

Physiochemical properties of goat milk compared to Cows, milk

Table 1 shows the physiochemical composition of the two species milk, the results revealed significant (P≤0.05) differences in majority of physiochemical properties of goats and cows' milk. However, minerals (Calcium and phosphorus) in the two milks (goats and cows) secured insignificant (P≥0.05) different. It was observed that protein and SNF in goat milk (3.500±0.329, 9.200 ±0.521) were higher than that found in cow milk (3.300±0.329, 9.08±0.521). The average of Protein content of goats' milk in this study was similar to that estimated by Wilson (1984) 3.4%. The average of Lactose in the present study was 4.85 % is similar to that found by Elamin and Wilcox (1992) 4.2%. Moreover, (Byoumi, 1990) estimated it as (5.5%), the difference may be due to the stage of lactation, as documented that, lactose % increased gradually at the commence of parturition until it reached 5.58% at the tenth day. Generally lactose content of goat milk varies greatly depending on feeding and watering conditions (Yagil and Etzion, 1980 and Yagil, 1994). Total solids and ash values in the presents study both were higher than those obtained by Aisha (2009) 11.3% and (Rehab, 2013) 0.73% respectively. Calcium and phosphorous concentrations in this study were lower than those found by Aisha (2009) and Gorban and Izzeldin (1997), the difference might be attributed to seasonality. The acidity in the present study was higher than that reported by Aisha (2009) 0.18%, and similar to that reported by Karim and Gooklani (1987) the difference may be due to breed factor. Furthermore, PH value in this study is similar to that reported by Mahmud (2009) and higher than that obtained by Rehab (2013) differences may be due to breeds and also, may be due to the analytical procedure applied, or to lactation stage.

Table 1 - Physiochemical analysis of cows and goats' milk.

Parameters	Treatments (Mean ± S.E)		Level of significant
	Cow Milk	Goat Milk	
Moisture	87.720^{a}±0.670	87.250^{a}±0.670	***
Fat	3.20±0.115	3.550±0.115	***
Protein	3.300^{a}±0.329	3.500^{b}±0.329	***
Ash	0.790±0.306	0.840±0.306	*
Lactose	4.990^{a}±0.163	4.86^{a}±0.163	*
TS	12.280^{a}±0.618	12.75^{a}±0.618	***
SNF	9.08^{a}±0.521	9.20^{b}±0.521	***
pH	6.660 ^{a}±0.231	6.35^{a}±0.231	NS
Acidity	0.180^{a}±0.029	0.170 ^{a}±0.029	***
Calcium	117.000±7.627	121.500±7.627	NS
Phosphorus	85.000±4.082	88.000±4.082	NS

TS= total solids, SNF= solids-not-fat. In this table and the successive one; mean in the same column not followed by the same common letter(s) differ significantly at (P < 0.05).

Physiochemical characteristics of cheese of cows and goats' milk

The data pertinent to physiochemical characteristics of goat's and cow's milk cheese is illustrated in Figure 1 The statistical analysis revealed significant (P≤0.05) differences among cheese physiochemical characteristics for the two species. It was noticed that acidic cheese prepared from goat's milk had higher contents of protein, fat, ash, TS, TNF and phosphorus. While acidic cheese from Cow's milk; showed high moisture, lactose, Ca^{++} and acidity. Moreover, enzymatic goats' milk cheese secured high percentage, of protein, fat, ash, TS, Ca and acidity. Whereas, cow's milk cheese which coagulated by enzyme revealed high percentage, of moisture, lactose, ph., TNF and Phosphorus. The average moisture of goat's enzymatic cheese in the present work (61.33 %) is similar to that demonstrated by Allahgabo (1986) he also found 61.33% for the moisture of cheese processed from goats' milk. The average protein (14.33%) obtained in this study is higher than that found by Adorkour (1992) 12.36% but,

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similar to that reported by Abdel Razig (1996). The fat percent in this study was also significantly (P≤0.05) higher (15.67%) than that found by Allahgabo (1986), who reported fat content of 12.65%. The total solid calculated in the present work is 36.67% however, was slightly lower than that reported by Ibrahim (1999) 36.75 %, and also, lower than that found by Mortada et al. (2013) 33.77%.

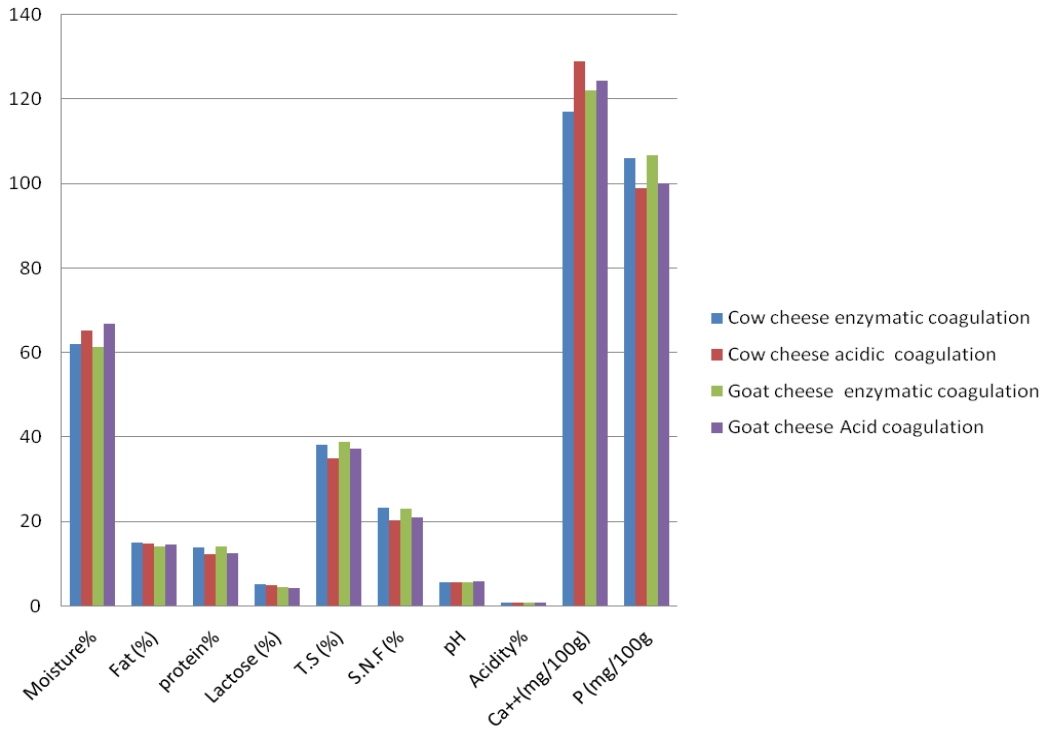

Figure 1 – Physiochemical characteristics of chees of cows and goats' milk

Effect of type of milk and coagulation agents on sensory evaluation of Cheese

Table 2 demonstrates the sensory evaluation of cheese processed from cows and goat's milk using rennet and lemon juice as coagulants. The statistical analysis revealed significant (P≤0.05) effect on all cheese sensory characteristics (taste, flavor, smell, texture, color and overall acceptability). The evaluation of panelists disclosed that best value for the taste, color and overall acceptability were obtained from enzymatic (rennet) goat's cheese followed by enzymatic (rennet) cow's cheese, then acidic (citric) cow's cheese and the last one was acidic (citric) goat's cheese treatment. Whereas, the best preferences for hardness and texture were obtained respectively, from enzymatic (rennet) cow's cheese, acidic cow's cheese, enzymatic (rennet) goat's cheese and acidic (citric) goat's cheese. However, the best values of smell were attained from enzymatic (rennet) cow's cheese, acidic (citric) cow's cheese, acidic (citric) goat's cheese and enzymatic (rennet) goat's cheese respectively, while the best flavor was recorded by the cheese manufactured from acidic (citric) cow's cheese, then enzymatic (rennet) goat's cheese followed by enzymatic (rennet) cow's cheese and acidic (citric) goat's cheese respectively.

Table 2 - Effect of coagulants on Sensory Evaluation of manufactured cheese from cow and goats' milk

Parameters	Treatments (Mean±SE)				Grant mean	Level of significant
	cow's cheese (Enzymatic)	cow's cheese (Acidic)	Goats' cheese (Enzymatic)	Goats' cheese (Acidic)		
Smell	7.70±0.70	7.30±0.75	6.50 ±0.79	6.90±0.64	7.10±0.35	***
Color	7.90±0.59	7.60±0.65	8.80±0.57	7.20±0.49	7.88±0.29	**
Flavor	6.90±0.66	7.40±0.67	7.20±0.68	6.50±0.83	7.00±0.35	**
Taste	7.10±0.67	7.50±0.64	7.80±0.63	6.30±0.58	7.18±0.32	***
Hardness	8.10±0.71	8.50±0.45	7.50±0.62	5.60±0.60	7.43±0.34	**
Texture	8.20±0.51	7.90±0.59	7.90±0.60	5.80±0.55	7.45±0.31	**
Over all acceptability	8.20±0.44	8.00±0.56	8.10±0.46	6.40±0.54	7.68±0.27	**

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The final Cheese yield

Figure 2 shows the effect of co-aggulation type on final weight, it was found that the white cheese obtained from cow's milk that coagulated with rennet enzyme exerted lower total weight than the that obtained from the same milk using Lemmon juice (citric acid coagulant), while the cheese obtained from goat's milk using rennet enzyme coagulant was recorded lower total weight than the that obtained from the same milk using Lemmon juice (citric acid coagulant), where the values of weight of the final Sudanese cheese (Gibna Bayda) obtained for the two treatments of cow's and goat's white cheese using rennet and acid coagulant were (0.640 kg, 0.735kg, 0.720kg and 0.785kg, respectively. The findings revealed that the weight of the final products obtained from cow's and goat's milk using citric acid coagulant were higher than that attained from the same milk using rennet enzyme coagulant. This may possibly be due to the fact that goat milk has higher total solid fat and protein content than cow milk. These findings were not in line with those obtained by Akinloye and Adewumi (2014). They found that the yield of cheese produced by using lemon juice extract were significantly lower than the other 2 coagulants used in their experiments.

It is possible to conclude that *lemon citrus* juice can be utilized as an alternative coagulant in production of local Sudanese white cheese for availability, high yield and short curdling time which performed favourably with the commonly used rennet enzyme. Further researches are needed to improve cheese yield and sensory characteristics using lemon juice as coagulant.

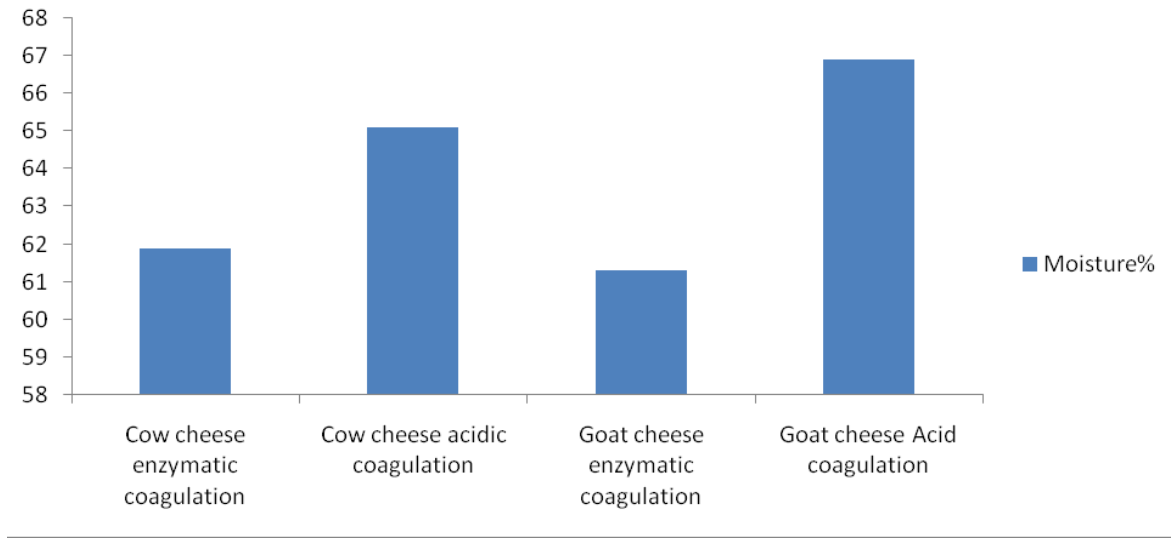

Figure 2 – Effect of co-aggulation type on final chees weight

CONCLUSION AND RECOMMENDATION

It is possible to conclude that lemon citrus juice can be utilized as an alternative coagulant in production of local Sudanese white cheese for high yield and faster curdling time which performed favourably with the commonly used rennet enzyme.

DECLARATIONS

Authors' contribution

Bhagiel BI performed data statistical analysis. Hamid EE conducted the lab work. Hamza AE contributed in writing, revising and printing manuscript, final draft.

Acknowledgment

We acknowledge the cooperation and help of laboratory staff of department of food technology, college of agricultural studies, university of Sudan for science and technology, Khartoum, Sudan.

Competing interest

The authors declare that they have no competing interests.

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2018 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 8, Issue 3: 52-58; May 25, 2018

ISSN 2228-7701

CHALLENGES AND MARKETE OPPORTUNITIES OF CATTLE FATTENING AROUND GONDAR TOWN, ETHIOPIA

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ABSTRACT: A study was conducted to assess cattle fattening opportunity, challenges and marketing system from January to May, 2017. The primary data was collected from purposively by interview in selected 50 cattle fattener households. According to the respondents, information color was the major selection criteria for fattening purpose with the proportion of 28% red coat and 10% for bulla (mixed color), 8% for white and 44% for black colors, whereas castration of animals was another fattening criterion for in the study area. Accordingly, about 6% of the respondents were fattened the castrated animals while the remaining 94% were the uncast rated bulls. Almost all respondents indicated that concentrate (10%), roughage (8%) and both concentrated and roughage feeds (82%) were the used feed sources for fattening purpose. Deciding finishing period of fattening cattle in the study area were based on live weight change (58%), by calculating feeding length (4%) and 38% of the respondents were used both. Market information is a crucial issue to reduce information gaps and uncertainties that existed in the livestock sector. The price of fattening cattle depends on weight and age of the animals. Lack of capital (40%) was the main constraint to begin cattle fattening and other constraints were shortage of feed and water, insufficient land, occurrence of disease and lack of awareness in order of importance 26.67%, 16.67%, 10%, 6.67%, respectively. And the opportunity of the area is also livestock access, meat demand of people increase and butchers house. Therefore, from the present study, it can be concluded that cattle fattening in Gondar town is one of the potential strategy to improve the livelihood of the family and had a good potential of market flow.

Keywords: Cattle Fattening, Constraint, Opportunity, Challenges, Opportunity

ORIGINAL ARTICLE

pii: S2228770118000008-8

Received 04 Aug. 2017

Accepted 20 Apr. 2018

INTRODUCTION

Globally beef and veal production is forecast at reached about 59.0 million tons (USDA, 2016). Since in the world, meat production is anticipated to record a modest expansion in 2015 to 318.7 million tones, 1.3 percent, or 4 million tons (Belachew, 2004) growth in of meat trade is projected to decelerate compared to the past decade. Globally almost 11% of meat output will be traded; Ethiopia is endowed with largest livestock production which ranks first in Africa and tenth in the world which has much to gain from the growing global markets for livestock products (CSA, 2013). Livestock become the integral part of Ethiopia's agricultural sector and plays a vital role in the national economy.

At present, livestock contributes about 20% of the growth domestic product (GDP), supporting the livelihoods of 70% of the population and the sub sector also account 11% of annual export earnings (Ministry of Economic Development and Cooperation, MEDC, 2010). According to the report of Bureau of Finance and Economic Development of Amhara Region (BoFED, 2004), the agricultural sector in the Amhara region contributed nearly 64% to the regional GDP between the periods 1994 to 2001. It is also known that Ethiopia is characterized by a high livestock population with low productivity of animal products, in terms of conventional products such as meat

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and milk. Despite the large number of livestock, there has been a decline in national and per capita production of livestock, livestock products, export earnings from livestock and per capita consumption of food from livestock (CSA, 2013).

Global meat trade is forecast to expand at a moderate rate of 1.7 percent in 2015, to 31.2 million tones, a significant slowdown from the 3.1 percent registered last year (Belachew, 2004). Meat production and consumption is important in the Ethiopian economy and ruminants contribute over 3.2 million tons, representing over 72% of the total meat production (Belete et al., 2010). Even if, the Cattle population in the majority of tropical country is higher, there is a strong unsatisfied demand, due to the increment of population growth in the majority of tropical countries, for milk and meat (FAO, 2015). However, the actual consumption is seriously restricted by the low purchasing power of the majority of the consumers, for whom retail prices are already too high. At the other extreme, the producer is in a difficult position and the course taken, notably for beef, does not allow to envisage the introduction of more intensive techniques, the only ones which would enable an increase in production when the limits of expansion of the pasture area are reached (Azage and Alemu, 2008).

According to MOA (1996) report, in Ethiopia there are three different types of beef fattening systems. Those are traditional, by-product based fatting and Hararghe fattening system. Each of the production systems had their own characteristics and had positive and negative impacts. Formally, Ethiopia exports approximately 200,000 livestock annually (Belachew, 2005). This is significantly higher than the annual official exports of cattle (12,934 head), sheep (13,554 head) and goats (1,247 head) between 1998 and 2003 (Belete, 2006). In Ethiopia, recent studies estimated that annual illegal flow of livestock through boundaries reaches as high as 320,000 cattle (Belete et al., 2010). This being the potential for export, the actual performance has remained very low, leaving most (55 to 85%) of the projected livestock off take for the unofficial cross-border export and the domestic market. There are a number of challenges and negative impacts which limits profitability of beef cattle production systems in Ethiopia.

Information on production system, marketing and constraints of beef cattle production in the study area are very rare. In north Gondar there was estimated to have less supply of crop-residues, there may be mishandling and lack of awareness about crop-residue improvement (Bureau of Agriculture and Rural development, Board, 2004). As a result, utilization efficiency of the residues was low. Lack of proper selection of fattening cattle, fattening practice, lack of market information and also poor managements in relation to feeding system, healthcare, housing etc. reduced the performance of cattle fattening (Board, 2004). Hence, the producer may not get reasonable benefit from their fattening activity unless appropriate improvement strategies have to be introduced. In addition to this, detail studies on sources of feed available for cattle fattening, constraints and marketing system of cattle in the area was not further studied, therefore the specific objectives of the research was to assess the major challenges of cattle fattening in and around Gondar area and to identify market opportunities and constraints of cattle fattening in the study area.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in and around Gondar town of Amhara Region State, Ethiopia started from March to May, 2017. The area is located at a distance of 737 km away from Addis Ababa and North West of Amhara region. The area lies between an altitude of 12o35'60''N and longitude of 37o28' 20''E and has an elevation of 2300 m.a.s.l. Gondar has a varied landscape, dominantly covered with ragged hills and plateau of land formations. The annual average temperature and rain fall were 19.70c and 1772 mm respectively which could be categorized under mid highland climatic zone. The area is also classified mainly in to two seasons, the wet season, ranging from June to September and the dry season extended from October to May (CSA, 2000).

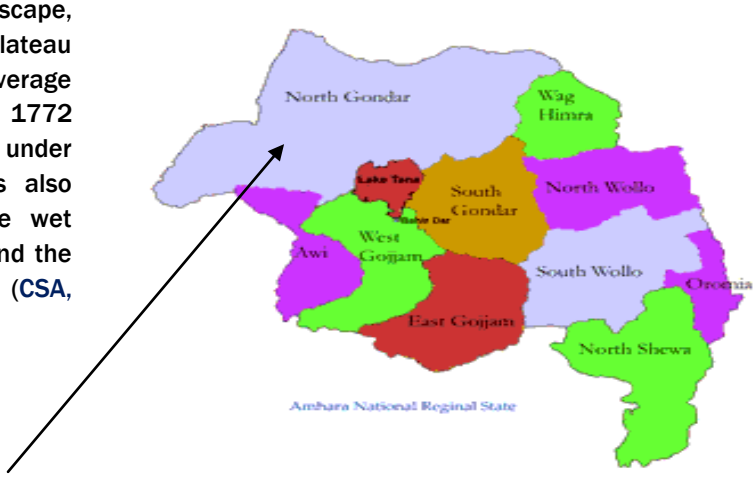

Figure 1. Map of North Gondar town indicated as the study area on the map of Amhara regional state

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Data collection and sampling techniques

Primary data was collected from the respondents using a semi structured questioner on purposively selected peasant associations (PA's) in and around Gondar area. A total of 50 respondents were purposively selected during the survey and the data obtained from the survey was managed in excel spread sheet for further analysis. Additional information was collected from of secondary data was also collected using district livestock d3velopment agency office.

Data Management and Statistical Analysis

The data was managed in excel spread sheet and transferred in the statistical software with Statistical package for social science (SPSS) version 22 software. Simple descriptive statistics like frequency and its distribution and percentages, mean separation, chart analysis and important procedures were employed during the analysis of the primary and secondary data of the research outputs.

RESULTS AND DISCUSSION

Socio Economic Characteristics of the House Hold

Socio economic characteristics of the house hold is presented from (Table 1). According to the present study almost all respondents 100% were with the fixed or sub effect of sexes. Whereas the overall proportion marital status of the community in the study area were married, single and divorced with the frequency of 66, 26 and 8%, respectively. Area was married and among them 100% of males were the responsible person on fattening activity. 27% of fattener participants were between the ages of 36-45 yrs and 46% of respondents their educational level were elementary school. The average age of the households involving on fattening practices were similar with that of MEDC (2002) which was the average age of the fatteners involving on fattening in a range from 36-45 yrs old.

Cattle fattening practice and selection criteria in the area

The research result depicted that, from the total household respondents 19 (38%) were select the Fogera breed or Fogera type for fattening while others used borane 21 (41%) and exotic 13(26%),other breeds are 15(30%) as fattening cattle of which, coat color were also used as preference that was red coat color14 (28%) cattle for fattening purpose and bulla (mixed color) 5(10%), white 4(8%), black were 22 (44%), other 5(10%) respectively. Castration of animals was also another criterion for fattening in the study area. Accordingly, 6% of the respondents fatten castrated animals while the remaining 94% of the respondents were fattening the uncastrated bulls (Mohamedsaleem and Abate, 2010). Cattle Fattening, Constraints and Marketing System in North Western Ethiopia are similar with our finding. And type of breed used for fattener is Fogera, Borena ,exotic, and other an mentioned breed 38%, 6%, 26% and 30% respectively. According to the finding of the present study one of the criteria's of fatteners to select animals before fattening were based on the animals coat color however, this criteria's were not agreed with that of the report of Belete et al. (2010) almost all traders do not take coat color as a criterion for selection of beef animals.

Phenotypic characteristics and breed preferences for fattening

The research result showed that, 24 (38%) of the respondents was selected Fogera breed for fattening where as other few 8 (6%) used Borena breed while 18 (26%) of the respondents was used exotic (cross bred) cattle this may be the farmers found in the vicinity of the fattening area may have the experience of using artificial insemination or crossing with other exotic animal breed. the result depict that, 47 (94%) of the fatteners were used uncastrated animal while, few 3 (6%) of them was used castrated cattle for fattening, this might be due lack of awareness about the difference in feed conversion efficiency of castrated and none castrated bulls in which castrated animal has high in body conversion efficiency than none castrated bulls during the feeding process. The majority of cattle fatteners have the experience of selecting color preference of which, 22 (44%) of the owners prefers black animal for fattening while the second preference 14 (28%) was red coat color, these might be due to either the dominant color in the market area were black and red in color or market price for those color might be relatively inexpensive.

Feed Sources and dry matter in take

The major feed sources which were used for cattle feeding for fattening in the study area were found to be both concentrate and roughage 41 (82%) while, sole feed contribution was 5 (10%) and 4 (8%) concentrate and roughage feed respectively, while, the sources of drinking water was natural river water accounted 50(100%) in the research site. Again, the research findings depicted that, the dry matter intake of the cattle ranges from 13-14 (10%), 15-16 (54%) and greater than 16 kg (36%) were found correspondingly.

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Methods to decide finishing period of fattening cattle

The research result depicted that, the market decision after finished the cattle were showed that, 2 (4%), 29 (58%) and using all the 19 (38 %) were employed the feeding length, live weight and both were found to rich to the market for sell. while, the finished period of the fattened cattle was ranged from only three month. and between three and four month were found to be 37 (74%) and 13 (26%) of the respondents finished their animal and supply to the market for selling respectively.

The present findings has in agreement with that of the research result, Takele and Habtamu (2009) and BoARD (2004) who reported that cattle feeders fed their animal usually for four months in southern and northern Ethiopia, respectively. However, this study was in contrast with that of Tolera and Abebe (2007), farmers in east Ethiopia fed cattle for more than one year which was also significantly exceeds with the average fattening period in Southern parts of Ethiopia.

Market information for fattening cattle

The price of fattening cattle depends on weight and age of the animals. Hence, fattening more closely resemble to fattening of culled cows, however, the fattener decide the end of finishing period of fattening cattle by considering rate of live weight change in the study area. However this was in agreement with the findings of Alemayehu (2002). Market information is crucial to reduce information gaps and uncertainties that exist in the agricultural sector. It is required by producers in their planning of production and way of marketing the product then in the present study all fatteners have market information. market price according to sample respondents, average maximum and minimum price for fattened cattle in the study area was 46% of respondents sold their fattened cattle on average price of (17501-18500Etbr), 32% (16501-17500Etbr), 18% (18001-19500Etbr), 2% (15000-16500Etbr) and 2% (19501-21000Etbr) respectively. And the price is determined by both the sellers and buyers negotiation, and price fluctuations were present for all respondents due to the cause of holyday throughout the year. All the fattened cattle were sold to Addis Abeba due to the reasons embargo of Sudan trade. And for whom to sell were 8% local buchers and 92% for whole sellers.

Major constraints cattle fattening in the study area

The research result showed that, a significant variation was observed between feed and water shortage which were 19 (38%) and 13 (26%), while other problems like lack of water, market, feed, land, credit and extension service) accounted 18 (36%) of the total respondents correspondingly. The bottle neck for livestock production in the study area become feed shortage and the finding was clearly indicated due to human population increase in alarming rate and competition with arable land in the study area become high.

The present study was similar with the finding of Belete et al. (2010) reported that the critical constraints to improve dairy and beef cattle production in the district were feed shortage, high disease prevalence, shortage of improved dairy breeds, poor extension service, Artificial Insemination (AI) and veterinary services, lack of working capital, marketing problems for dairy and beef products during the long fasting periods, lack of market information system and lower purchasing power of the local consumers in Amhara region of Ethiopia. However, it was in contrast with Getnet (2003) reported that feed quality and quantity is the main limitation to animal production in Ethiopia.

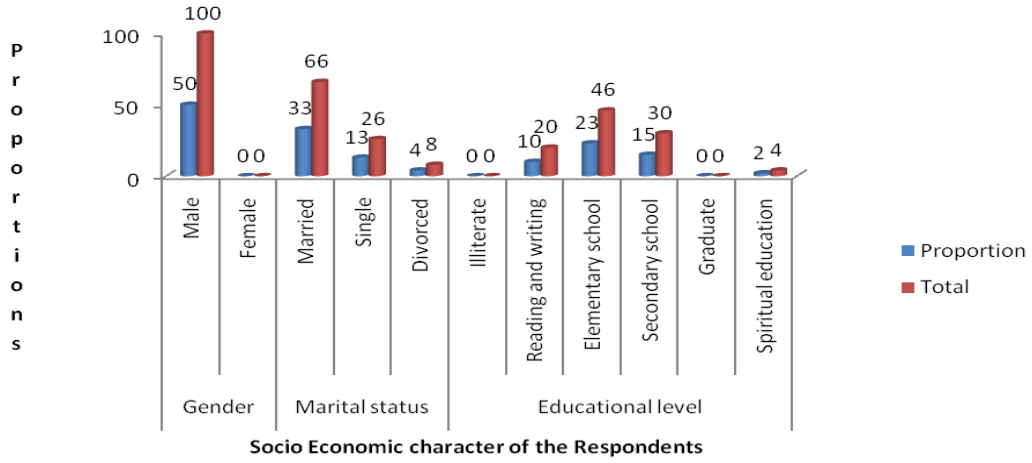

Figure 2. Socio-demographic characteristics of the respondents in the study area

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Table 1 - Preferable Selection Criteria for Beef cattle fatting

Major Factors	Preferred Issues	Frequency	Percent
Type of breed	Fogera	24	38
	Borena	8	6
	Exotic	18	26
	Total	50	100
Type of cattle fattened	Castrated	3	6
	Un castrated	47	94
	Total	50	100
Type of color preferred	White	4	8
	Grey/Bulla	5	10
	Black	22	44
	Red	14	28
	Other	5	10
	Total		100

Table 2 - Major source of feed and dry matter intake

		Frequency	Percent	Mean	Std.dev
Source of feed	Concentrated	5	10	2.72	0.64
	Roughage	4	8		
	All	41	82		
	Total	50	100		
Amount of feed per day in kg	13-14	5	10	3.26	0.633
	15-16	27	54		
	>16	18	36		
	Total	50	100		
Source of water	Rivers	50	100	2	0

Table 3 - Market decide and finishing period for fattening cattle

		Frequency	Percent	Mean	Std.dev
Market decide	Using feeding length	2	4.0	2.72	1.031
	live-weight change	29	58.0		
	All	19	38.0		
	Total	50	100.0		
Finishing period	Three month	37	74.0	2.52	0.886
	Three to four month	13	26.0		
	Total	50	100.0		

Table 4 - Market opportunity on fattening cattle

	Market area		Frequency	Percent	Valid Percent
Marketing place	A/Ababa		50	100.0	100.0
Customers	Buchers		4	8.0	8.0
	whole seller		46	92.0	92.0
	Total		50	100.0	100.0
Average price	15000-16500		1	2.0	2.0
	16501-17500		16	32.0	32.0
	17501-18500		23	46.0	46.0
	18501-19500		9	18.0	18.0
	19501-21000		1	2.0	2.0
	Total		50	100.0	100.0
Price fluctuation	Yes		50	100.0	100.0
	no		0	0	0
Criteria to purchase	Sex	Male	39	78.0	78.0
		Female	0	0	0
	Age	Adult	7	14	14
		Young	4	8	8
	Total		50	10 0.0	100.0
Market information	Yes		50	100.0	100.0
Determine the price	Negotiation		50	100.0	100.0
Price difference	Yes		50	100.0	100.0

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Table 5 - Constraints of cattle fattening in the area			
Major problems	**Frequency**	**Percent**	**Percent**
Shortage of water	**13**	**26**	**26**
Shortage grazing land	**19**	**38**	**38**
Lack of water, market, feed, land, credit and extension service	**18**	**36**	**36**
Total	**50**	**100**	**100**

CONCLUSION

The overall results of the present study showed that the major occupation of households in the study area was depending on livestock production. Fatteners using oxen for fattening purpose are, black coat color and uncastrated. The feed sources used for cattle fattening are bean straw, nuge cake, chick pea, wheat bran, barely straw and teff straw, maize and hay. The major constraints for fattening practices is lack of initial capital, shortage of feed and water, land shortage, occurrence of disease and lack of awareness. Generally, cattle fattening practices is one means of household livelihood improvement Gondar town. Based on this information, it is recommended that, the government should give due attention on market channels of fattened animals in Gondar town. Extension policies and strategies on fattening practices, feed improvement strategies, credit service, training and extension service (advice on beef selection, feeding, health care and market information well organized stake holder)and further researches on reproductive performance of fattening cattle and carcass quality related to feeding in Gondar town should be conducted.

DECLARATIONS

Authors' Contribution

I contribute on data analysis and the write up of the manuscript and the other authors were participated on data collection and gathering information for this paper.

Conflict of interests

The authors have not declared any conflict of interests.

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2018 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 8, Issue 3: 59-73; May 25, 2018

ISSN 2228-7701

SMALL RUMINANT PRODUCTION SYSTEMS AND BREEDING PROGRAMS IN ETHIOPIA: ACHIEVEMENTS, CHALLENGES AND LESSONS LEARNED: A REVIEW

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Supporting Information

REVIEW

PII: S222877011800009-8

Received: November 14, 2017

Revised: May 23, 2018

ABSTRACT: Indigenous small ruminants (sheep and goats) in Ethiopia are very important sources of both tangible and intangible benefits to resource-poor farmers. To date, the country has more than 60 million heads of shoats raised in different production systems, yet their productivity and contribution to the agricultural and national economy is far below the potential. Limited genetic potential has been identified as a major constraint to increased productivity. Various small ruminant genetic improvement programs, aimed at improving the productive and reproductive performance of indigenous breeds, were therefore implemented in the country. Crossing local breeds with their exotic contemporaries was one of such programs commenced since 1944 on sheep and the mid-1970s on goats. Due to different reasons, however, the small ruminant crossbreeding programs in Ethiopia did not deliver the anticipated benefit to smallholder farmers and hence many of the crossbreeding programs were failed. Following the tragic and fruitless ending of small ruminant crossbreeding programs, centralized nucleus-based selection programs were then implemented widely in different parts of the country with the objective to achieve highly productive and prolific genotypes. Despite several efforts made towards this end, the selection programs in various nucleus centers did not provide the desired genetic improvements and generally yielded unsatisfactory results. As a result, a viable option that fits well with the prevailing low input production systems was therefore required. One such option that has recently stimulated a global interest was community-based breeding program. The program was implemented and tested in Ethiopia as early as 2003 on the adapted local breeds in four regions across the country. It had a promising start and by now it realized several achievements. Hence, the program should be part of the national livestock breeding policy.

Keywords: Breeding Programs, Ethiopia, Production systems, Small ruminants

INTRODUCTION

Small ruminants (shoats) in Ethiopia are important sources of both tangible (income, meat, milk, skins and manure) and intangible (saving, insurance against emergency, cultural and ceremonial) benefits that vary among different cultures, socio-economies, agro-ecologies and locations (Workneh et al., 2003; Kosgey, 2004). To date, the country has more than 30.7 million heads of sheep and 30.2 million heads of goats (CSA, 2016); nine sheep (Gizaw et al., 2007) and seven goat (Mekuriaw, 2016) breeds kept in diverse production systems and different agro-climates ranging from the hot arid and semiarid areas to the cold humid highlands. Estimates indicate that 99.72% of the sheep and 99.97% of the goats are indigenous breeds (CSA, 2016) that are evolved to survive in harsh environments at the expense of all other factors (production included).

In Ethiopia, almost all sheep and goats are produced in mixed crop-livestock and pastoral and agro-pastoral production systems characterized by low levels of input and technologies, feed scarcity and disease challenge (Alemayehu, 2006). The mixed crop-livestock production system is often found in the highland agro-ecological zones where livestock production is secondary to crop production. The system comprises of very small flock sizes due to shrinkage of grazing areas per household, limited feed availability and land degradation (Tesfaye, 2004; Solomon et al., 2014). On the other hand, the pastoral and agro-pastoral production systems are found in the arid and semi-arid agro-ecological zones where the majority of small ruminants are concentrated. These areas are the

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major sources of livestock products for the Ethiopian export market (Solomon et al., 2010; Legese and Fadiga, 2014). The pastoral system is based on wide-ranging communal grazing lands primarily using natural vegetation where thorny enclosures are common while the agro-pastoral system is characterized by a combination of pastoral and mixed crop-livestock production systems with periodic use of crop residues (Grum, 2010).

Given large number of indigenous sheep and goats, their contribution to the agricultural and the overall national economy is however far below the potential (Legese and Fadiga, 2014). Similarly, compared to all other countries and the global average, the productivity of Ethiopian small ruminants is reported to be one of the lowest. This could be attributed to their various interactive factors such as poor genetic performance exacerbated by low input traditional production system (Gizaw et al., 2008). Cognizant of this fact, a number of sheep and goat improvement programs, aimed at improving the performance of indigenous breeds without losing their capacity to survive in harsh environments, were conducted in the past (Workneh et al., 2003).

One of such programs was crossbreeding the indigenous breeds with temperate breeds to combine high yielding capacity of exotic genotypes with better adaptation attributes of their indigenous counterparts (Tesfaye, 2004). However, the belief that crossbred genotypes have better performance than indigenous breeds led to indiscriminate crossbreeding (Gizaw et al., 2013). In fact, few crossbred sheep and goats equally combined both production and adaptation features and performed better than the indigenous breeds under on-station conditions; yet such superiorities were not replicated under on-farm management (Workneh et al., 2003). Hence, the adoption rates of exotic and crossbred genotypes by smallholder farmers were found to be very low (Teressa, 2004; Kosgey et al., 2006; Oumer and Firew, 2017) and their number remains insignificant (0.31%) (CSA, 2016). This indicates that small ruminant crossbreeding program in Ethiopia did not deliver the anticipated benefit and the smallholder farmers did not benefit more from crossbreds than from indigenous breeds (Workneh et al., 2003). As a result, most of the crossbreeding programs were not successful; rather they caused erosion and dilution of the adaptive features of the indigenous breeds.

Following the fruitless ending of various crossbreeding programs, centralized nucleus-based selection programs were then applied in the country. The programs were implemented on Afar, black head Somali, Horro, Menz, and Washera sheep breeds (Gizaw et al., 2013) and Arsi-Bale goat populations (Abegaz et al., 2014). The selection criteria were post-weaning growth rates, Pre-weaning weight gain, litter size and yearling weights (Gizaw et al., 2013). Nevertheless, the improvements obtained from these nucleus-based selection programs, except the Menz program, were found to be unsatisfactory and improving the performance of small ruminants through such programs is still a challenge in Ethiopia.

The failure of the small ruminant crossbreeding and nucleus-based selection programs in Ethiopia initiated the implementation of a very recent approach called community based breeding program (CBBP) on the adapted local breeds. Due to its multidimensional benefits and fitness to the existing low input production systems, CBBP is a feasible alternative for Ethiopian smallholder farmers (Haile et al., 2011; Wurzinger et al., 2011). The program was employed in the country as early as 2003 on Afar, Bonga, Horro and Menz sheep breeds (Gemeda, 2011; Mirkena, 2011) and Abergelle goat populations (Solomon, 2014) by the national agricultural research centers in collaboration with the international research institutions (Gutu et al., 2015).

Overall, large number of sheep and goats in Ethiopia are reared in diverse production systems and several crossbreeding, nucleus-based selection and community-based breeding programs, directed towards improving the performance of indigenous breeds, were executed in the past several years. However, there is lack of organized and up-to-date information on small ruminant production systems and breeding programs in Ethiopia. This paper, therefore, aims to review and discuss the achievements recorded so far, challenges encountered and lessons learnt in the Ethiopian small ruminant production systems and breeding programs.

DISCUSSION

Role and productivity of small ruminants in Ethiopia

Small ruminants in Ethiopia play very crucial role in terms of meat, milk, manure, skin, wool, horn, bone, security, gifts, religious rituals, medicine and incentives (Legese and Fadiga, 2014; Zahra et al., 2014). Currently, small ruminants in Ethiopia contribute 154,000 tons of meat (Mourad et al., 2015), about one-fourth of the domestic meat consumption; half of the domestic wool requirements; 40% of fresh skins and 92% of the value of semi-processed skin and hide export trade. At optimum off-take rates, Ethiopia can export 700,000 sheep and 2 million goats annually, and at the same time supply 1,078,000 sheep and 1,128,000 goats for the domestic market (Adane and Girma, 2008).

Given their multiple roles, the current level of indigenous small ruminants' productive performance is however reported to be very low. For instance, carcass yield has been flat for the past several years and will remain so in the

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future. For the years (1999-2008), the average carcass weight produced from yearling sheep and goat in Ethiopia was only 10 and 8 kg, respectively and it was one of the lowest compared to all countries and the world average (16 kg for mutton and 12 kg for goat meat) (FAO, 2005). Therefore, the future growth in Ethiopian small ruminant meat production will come from increase in the number of slaughter animals or slaughter volume (Legese and Fadiga, 2014). Likewise, the dressing percentage (DP) of indigenous small ruminants at one year of age is also very low. The average dressing percentage of Ethiopian sheep were reported to be 42.5% (Berhe, 2010) while the same varied between 42 and 45% for goats.

The average annual off-take rate, defined as the proportion of animals sold or consumed in a year, for sheep and goats in Ethiopian smallholder farmers and pastoralists was also very low over different time periods (Asfaw and Jabbar, 2008). For the year 1999/2000, the average net commercial off-take rates of sheep and goats in the highland areas of Amhara, Oromia and Tigray regions were 22 and 18%, respectively while in the year 2004/05, the average net commercial off-take rate were 7 and 8%, for sheep and goats, respectively (Workneh, 2006). In the case of Borana pastoral production system, the average net commercial off-take rate of small ruminants was 7% (Asfaw and Jabbar, 2008). Ethiopian Privatization Agency (EPA, 2002) and Adane and Girma (2008) also reported that the annual off-take rate of indigenous sheep and goats were only 33 and 35%, respectively. Recent estimate of average off-take rate from sheep and goats, between 2008 and 2010, was 30-38% (ILRI, 2014, unpublished report; cited by Mourad et al., 2015). In parallel, the demand for animal products has increased due to a growing human population and urbanization. There is, therefore, an urgent need to improve productivity of small ruminants in order to raise smallholders' incomes and meet the demands of the growing human population (Haile et al., 2011).

The low productivity of small ruminants could be attributed to complex interaction of numerous technical, institutional and socio-economic factors such as: poor nutrition, inadequate veterinary services, persistent drought, disease, poor infrastructures, low levels of technologies, insufficient financial services and poor genetic performance (Aklilu, 2008; Solomon et al., 2010). Along with these factors, uncontrolled mating, negative selection practices through sale of best performing young animals (Getachew et al., 2010; Mirkena, 2010; Haile et al., 2011; Gizaw et al., 2013) and inappropriate livestock development policies (Aleme and Lemma, 2015) are becoming major factors for the poor performance of small ruminants. Lack of suitable policy in one hand and implementation of inappropriate policies on the other hand hindered the smooth progress expected of the livestock sector.

Therefore, for the Ethiopian small ruminants to be more productive and entirely play their role as a pathway for the development of the country, any intervention that improves their productivity is important in creating wealth and improving the standard of living of resource-poor farmers. For example, alleviating the challenges and constraints that determine and hamper their productivity could be one possible mechanism. Moreover, designing and implementing appropriate genetic improvement programs that can boost productivity per animal is another possible option in order to meet the ever increasing demand of small ruminant meat in the ever growing human population. This is especially so when one considers that the demand for animal products is expected to double over the next 33 years as a consequence of urbanization, population growth and increased income (Westhoek et al., 2011).

Reproductive performances of Ethiopian small ruminants

Good reproductive performance is a precondition for any successful genetic improvement program and it determines production effectiveness (Zewdu, 2008). Reproductive performance of sheep and goats depends on various factors including age at first lambing/kidding (AFL/AFK), lambing/kidding interval (LI/KI), litter size (LS) and twinning rate (TR). For example, AFL/AFK is a good indicator of early sexual maturity in ewes/does and it is an economically important trait as greater population turnover and more rapid genetic progress can be obtained when sheep or goats produce their first progenies at an earlier rather than later age. Early maturing females are also known to have a relatively long and fruitful reproductive life. Similarly, total life time production (life time lamb/kid crop) can be increased by encouraging first lambing/kidding at an early age (Amelmal, 2011).

The reported average AFL of Ethiopian indigenous sheep breeds ranges between 11.5 and 23 months (Zelalem, 2016) whereas the average AFK of most indigenous goats is between 12 and 14 months (Dereje et al., 2015). The present review shows that most indigenous sheep/goat breeds of Ethiopia tend to have their first lambs/kids before they are two years old. This indicates that the existing uncontrolled breeding practice in the traditional production system is in favor of early lambing/kidding of indigenous goats than the controlled breeding practices in the improved system. In fact, there is variation among indigenous sheep/goat breeds in AFL/AFK due to various factors like genotype, nutrition, disease or parasitic burden, year and season of birth in which the ewe and doe were born (through their effect on feed supply and quality during different seasons) In addition, lambs and kids born for twins had longer age at first lambing and kidding than their counterpart single born lambs and kids.

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Lambing/kidding interval (LI/KI), which is the interval between two consecutive parturitions, is another main component of reproductive performance. Available evidences show that the average LI for indigenous sheep breeds is between 6.6 and 13.6 months (Zelalem, 2016) while the average KI for indigenous goat breeds is within the range of 8.5 and 12 months (Dereje et al., 2015). However, there are variations in LI/KI among indigenous sheep/goats that may be due to variations in breed, season (Mengiste, 2008), year of lambing/kidding, nutrition, type of mating, parity of ewes/does, post-partum body weight and management practice (Gbangboche et al., 2006). In conditions where good management, adequate nutrition and breeding males are available in the flock for most time of the year, shorter LI/KI can be achieved whereas longer LI/KI are mainly due to the result of controlled breeding, poor management and nutrition.

On the other hand, litter size (LS), a trait largely determined by ovulation rate, is reported to be between 1.02 and 1.51 for indigenous Ethiopian sheep (Zelalem, 2016) and between 1.07 and 1.5 for goats (Dereje et al., 2015). Ovulation rate is in turn dependent on age of the dam, level of nutrition, type of breed, season and dam body weight at mating (Mukasa-Mugarwa and Lahlou-Kassi, 1995) and management system (Mekuriaw et al., 2013). For instance, age of the dam has an effect on the number of lambs/kids born per lambing/kidding in such a way that LS is increased with an increase in parity and the highest LS is attained at six years of age or the fifth parity (Berhanu and Aynalem, 2009). Peak prolificacy is generally achieved between 4 and 8 years of the dam (Notter, 2000). Similarly, level of nutrition has an effect on LS in that, poor nutrition during service period lead to reduced ovulation rate and increased embryonic mortality and consequently decreased LS.

Moreover, most indigenous goats have twining rate (TR), the percentage of ewes/does having twins, below 20% varying from less than 5% for pastoral goats in arid areas to 36% for goats in the humid areas of the country (Dereje et al., 2015). Overall, LS and TR are the most variable traits reported for indigenous sheep and goats in Ethiopia. This shows the presence of huge opportunity to improve these traits through selection and improved management focusing on breeds having better potential for the traits. It is also found that LS and TR of some indigenous sheep and goat breeds are found to be lower than the values reported for most of the indigenous breeds in Ethiopia even under traditional systems which appear to be one mechanism of adaptation to the harsh environmental conditions of the rangelands and to the seasonal scarcity of feed resources.

Small ruminant production system in Ethiopia

Describing the production system in a holistic manner is a pre-requisite to design and implement a breeding program that can address the trait preferences and breeding objectives of smallholder farmers. To this extent, many studies were undertaken to describe the small ruminant production systems in Ethiopia since the mid-1980s (Samuel, 2005; Belete; 2009; Tesfaye, 2009; Zewdie, 2010; Alubel, 2015; Tsigabu, 2015; Zergaw et al., 2016) following the adoption of farming system research approach by the then EARO (Ethiopian Agricultural Research Organization) and now EIAR (Ethiopian Institute of Agricultural Research). Some of the reports were published in different journals, yet many more are neither reported nor accessed (Gizaw et al., 2013). Based on the level of the small ruminant production, their contribution to the community and the type of crop production enterprises, there are two major small ruminant production systems in Ethiopia: mixed crop-livestock and pastoral and agro-pastoral (Alemayehu, 2006) that can be distinguished mainly through the three production factors: land, labor and capital.

Mixed crop-livestock production system. Crop-based mixed farming system is often found in the highland agro-ecological zones where the altitude ranges between 1500 and 3000 masl and the climate is favorable for farming of crops and raising of livestock. In this production system, livestock production is secondary to crop production and it usually comprises of small ruminants with very small flock sizes as a means to generate cash income from sale of animals and produce meat (Tesfaye, 2004; Solomon et al., 2014). Sometimes, manure is returned to the system (nutrient cycling) to benefit vegetable gardens, food and cash crops. Here, mixed species (cattle, sheep, goats and other livestock) grazing system has been predominantly practiced (Lebbie, 2004) and livestock were freely grazed on communal pastures and seasonally on fallow crop lands with no extra-supplement. However, due to human population growth and urbanization, there is shrinkage of grazing lands from time to time (Workneh, 2000). Hence, in some areas, free grazing is limited and small ruminants are now tethered (Kidus, 2010) though they are herded in others to graze and browse on communal lands (Deribe, 2009; Tegegne, 2012). In addition, due to a gradual shift from keeping large to small ruminants, the relative importance and population of small ruminants is increasing and feeding animals in a limited available grazing lands, crop residues, forages, bushes and shrubs, home left overs and industrial by-products are becoming the features of mixed crop-livestock production system. Accessibility of water is not a limiting factor in most areas under this production system and goats are housed within the family house (Endeshaw 2007; Deribe 2009; Kidus, 2010) or in separate housing (Belete, 2009; Kidus, 2010; Dhaba et al.,

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2012). However, the system is characterized by low productivity due to recurrent drought, nutritional stress, severe resources degradation and internal and external parasites (EARO, 2000; IBC, 2004).

Pastoral and agro-pastoral Production system. The majority of small ruminants (40% of sheep and 40% of goats) are concentrated in the pastoral and agro-pastoral areas (Asfaw and Jabbar, 2008) kept under extensive systems which make them major sources of livestock products for the Ethiopian export market (Legese and Fadiga, 2014). In this production system, there is relatively lighter human pressure on natural resources and higher land holding per households than that observed in the mixed farming system. As the arid and semi-arid agro-ecological zones, within altitudes below 1500 masl, receive low moisture in most of the time and feed is scarce in the dry season, pastoralists and agro-pastoralists travel long distances with their animals in search of feed and water. The system is either transhumant (the whole system moving periodically) or sedentary (limited movement) (Solomon et al., 2008). The pastoral production system is based on wide-ranging communal grazing lands primarily using natural vegetation where thorny enclosures are common while the agro-pastoralists, on the other hand, are characterized by a combination of pastoral and mixed crop-livestock production systems with periodic use of crop residues (Grum, 2010; Legese and Fadiga, 2014).

Selection criteria and breeding objectives of small ruminants in Ethiopia

In designing breeding programs for most livestock species, selection is based on breeding values estimated using either selection index or, if possible, best linear unbiased prediction (BLUP). Based on the traits under consideration, these techniques require recorded information on the performance of the individual animal and its relatives (Mbuku et al., 2006). Such techniques are however too complex for the resource-poor farmers to apply, as they do not have records on the performance of individuals and their pedigree. Conversely, this does not mean that they do not consider the performances of the individual and its relatives when selecting animals to be parents of the next generation though no effective selection and breeding programs can be applied in the absence of records (Semakula et al., 2010).

Selection criteria of smallholder farmers reflect their breeding activities and farming philosophies and the criteria do vary among different production systems and species (Roessler et al., 2008). The criteria are also different between sexes. For instance, for males, appearance (Getachew, 2008), body size (Zewudu et al., 2012), tail type, color and height (Gizaw, 2008) are given due emphasis during selection. On the contrary, rams and bucks with black color, poor body condition and small size are not preferred for breeding purpose and male animals of such character are usually culled at a young age or sold or slaughtered at home. Similarly, in selecting ewes and does, appearance, coat color and lamb survival (Getachew, 2008; Niggussie et al., 2013) and liter size and lamb growth (Gemeda et al., 2011) were reported as the most important selection criteria, yet those of which are black colored, old aged, poor conditioned and those having long lambing interval are culled (Zewudu et al., 2012 and Yenesew et al., 2013).

Despite the variation in production system and sex, the small ruminant selection criteria in Ethiopia usually focused on a single market driven trait. For instance, fast growth rate, to produce sheep and goats that can fetch higher market price, was the primarily preferred trait in the crop-livestock mixed production system (Arse et al., 2013; Niggusie et al., 2013; Ahmed et al., 2015; Alubel, 2015; Tsigabu, 2015; Zergaw et al., 2016) while milk yield and meat production was the most preferred traits in pastoral and agro-pastoral areas (Getachew, 2008; Zewdu, 2008; Belete, 2009; Kahsa, 2009; Getachew et al., 2010; Gizaw et al. 2010; Alefe, 2014; Feki and Berhanu, 2016). Social and cultural functions were also ranked as other important aspects of small ruminant production (Mengistie et al., 2010; Assen and Aklilu, 2012; Fsahatsion et al.; 2013 and Solomon, 2014). However, the adaptive attributes that small ruminants would assume were not considered in the improvement programs and not captured in the economic analysis. This might lead to genotypes that are neither well adapted to the environment nor capable of performing multiple roles (Haile et al., 2011).

Hence, identifying the selection criteria of farmers and their breeding objectives, in a particular production system and environment, is very crucial to design and implement effective small ruminant genetic improvement programs (Jaitner et al., 2001; Jimmy et al., 2010; Wurzinger et al., 2011; Niggusie et al., 2013). In this state of being, the multiple values of indigenous small ruminants and non-tradable attributes such as adaptive features, tolerance to diseases and feed shortage would not be overlooked by giving rise to misplaced objectives. Furthermore, it is possible to extract more than just milk and meat and get the most out of these animals that can survive and reproduce under the harsh environmental conditions. In general, for developing countries like Ethiopia, where indigenous small ruminants are the most important livestock species in the livelihood of smallholder farmers, the development of single purpose specialized breeds is not an appropriate option.

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Small ruminant crossbreeding programs in Ethiopia

Adapted to the local environment, the indigenous small ruminants represent a unique genetic resource for the smallholder farmers. However, the need for increased economic gains and the belief that crossbred genotypes have better overall performance than the indigenous breeds led to indiscriminate crossbreeding of the indigenous breeds with exotic breeds (Workneh et al., 2003; Tesfaye, 2004). The small ruminant crossbreeding program based on exotic sires was therefore started in Ethiopia in 1944 with the introduction of the Merino sheep breed from Italy (DBSBMC, 2007). Since then, small ruminant crossbreeding has been the major component of the livestock genetic improvement endeavors and several on-station and on-farm efforts have been made on sheep (Tibbo, 2006; Gizaw et al., 2013) and goats (Abegaz et al., 2014).

For instance, Romney, Corriedale, Hampshire and Rambouillet sheep breeds were imported from Kenya in 1967 (BoA, 2000) and were crossed with local Menz breed to produce and supply finer and longer wool fiber for Debre Berhan blanket factory (DBHBMC, 2007; Gizaw and Getachew, 2009). The breeds and their resultant crosses had good growth and wool production performance under on-station and on-farm conditions. But, except Romney, the rest of the three breeds were not accepted by the local farmers due to their phenotypic characteristics (face covered with hair, absence of horn in males, thin tail, fatty nature of the wool making it difficult to spin in the traditional way and poor skin quality) (Getachew et al., 2016).

Later in 1980, pure Awassi rams were imported from Israel (DBHBMC, 2007) and were crossed with the local Menz ewes in Debre Birhan and Amed Guya multiplication centers. The resultant crossbred rams were then distributed to villagers when they were six months old. Finally, upgrading of the village flocks to 75% Awassi were undertaken (Gizaw and Getachew, 2009). The purebred Awassi and their crosses (Awassi x Menz) were accepted very well by Ethiopian farmers due to their similar physical appearance with the local Menz breed. However, the strategy to disseminate improved genotypes to the farmers and the scheme to sustain the crossbreeding at the community level were not well defined. As a result, indiscriminate crossbreeding and extensive distribution of crossbred rams across the country, in the last three decades, yielded virtually no impact on the sheep industry (Gizaw and Getachew, 2009; Gizaw et al., 2013). In addition, the rates of inbreeding per generation derived from the number of breeding males and females (BoA, 2001) were well beyond the acceptable level of 1.0% (6.1% at Debre Birhan and 32.5% at Amed Guya). This could be attributed due to small flock sizes which lead to mating of related individuals and inbreeding depression; 67 pure breed rams and ewes at Debre Birhan and 13 at Amed Guya ranches were kept by the end of 2004 (Gizaw and Getachew, 2009).

In the late 1980s, Dorper sheep were introduced into Ethiopia though they were looted during the political instability in 1991 (Awgichew and Gipson, 2009). In 2006, they were imported again from the Republic of South Africa by the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) (ESGPIP, 2006; Gizaw et al., 2013) with a financial support from USAID. After the importation of the breed, two nucleuses and ten Breeding, Evaluation and Distribution (BED) centers were established in different parts of the country by the ESGPIP in collaboration with local universities and research centers. However, the promising start faced the common tragedy of sheep crossbreeding programs in Ethiopia following the termination of funding and phasing-out of the ESGPIP in 2011 (Getachew et al., 2016). Currently, the various Dorper centers are being run with little national coordination. Despite this fact, there are encouraging regional Dorper sheep researches and development projects with rational crossbreeding schemes (Gizaw et al., 2013). A detail report on the on-station and on-farm research results on growth, reproductive and carcass performances of different sheep crossbreeding programs, based on exotic sires, in Ethiopia is presented in Getachew et al. (2016).

Crossbreeding among the local sheep breeds has also been practiced in many areas of the country. For example, the indigenous Washera rams were distributed to the highlands of North Shewa, South Wollo, North Wollo, and Gondar areas by Debre Berhan Agricultural Research Center as an alternative to the use of exotic sires for crossbreeding (ANRSBoARD, 2004; Getachew et al., 2016). In 2005, a village-based Farta × Washera sheep crossbreeding program has also been started by Andassa Livestock Research Center in Lay Gaint and Farta districts of South Gondar (Mekuriaw et al., 2013) with the aim to increase the productivity of medium sized Farta (Gizaw et al., 2008) by crossing with male and female Washera sheep. Improvement program on indigenous Farta sheep using indigenous Washera breed indicated that the growth performance of crossbreds was better than the pure Farta sheep (Mekuriaw et al., 2013).

Like that of the sheep, several goat crossbreeding programs have been implemented in Ethiopia to improve the meat, milk and fiber productivity of the local goat breeds. Introduction of exotic goats such as Saanen, Anglo-Nubian, Toggenberg and Boer was among the efforts made so far. Several comparison studies documenting the performance of different indigenous goat breeds and different blood levels of crossbreds were also reported by various scholars. The following are summarized reports.

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A study by Galal et al. (1982) on crossbreeding of Ethiopian highland goats with Saanen indicated a substantial increase in milk production from 19 to 52 kg in half-bred Saanen does (from a 12-week lactation), with a slight reduction in reproductive performance and a marginal increase in the growth potential of crossbreds. However, there have been adaptation problems for first crosses of Saanen and lowland goats in harsher areas, indicating that a lower level of exotic genotype might be more suitable.

A comparative study was also conducted on the productivity of indigenous purebred Adal and quarter-bred Saanen goats in Melka Werer Research Center (Awgichew et al., 1989). The same authors reported that crossbred does produced more milk than purebred Adal does and their progenies were heavier than purebred Adal goats at 3 and 6 months. However, breed had no significant effect on birth weight and 12 months weight. Further, there were no differences between purebred Adal and quarter-bred Saanen does in any of the reproductive traits recorded. It was thus concluded that, for the nomadic pastoralists around Melka Werer, the quarter-bred Saanen x Adal doe has much to offer.

Similarly, on-station comparison made between local goats and crossbreeds (local x Anglo-Nubian) in the FARM-Africa's dairy goat development project (DGDP) (FARM Africa, 1996) showed an increment in milk and meat outputs in crossbred goats, resulting an average increase in gross per capita income of 19% for the beneficiaries (Wagayehu and Habtemariam, 1994). The same authors noted, however, that the long-term success of local goats' genetic improvement program based on crossbreeding with exotic genotypes remains unproven. In similar study but with a different approach and after the completion of the DGDP, Workneh et al. (2003) found that crossbred goats (local x Anglo-Nubian) did not perform better than indigenous goats on comparisons based on land, metabolic weight and labor inputs.

Generally, given the host of examples available in the sheep and goat crossbreeding programs in different parts of the country, the on-station crossbreeding programs were successful with various achievements and crossbreds have superior performance than local breeds. However, such superiorities were not replicated under on-farm conditions and the resultant crossbreeds did not perform better than indigenous breeds. As a result, the adoption rates of crossbred genotypes by resource-poor farmers were found to be very low because crossbreds have no significant effects on their livelihoods and the national economy at large. On the other hand, the crossbreeding programs in Ethiopia caused erosion and dilution of the adaptive features of the local breeds and thus most of the small ruminant crossbreeding programs were unsuccessful and failed.

The major reasons for the failure of the small ruminant crossbreeding programs in Ethiopia are associated with the following documented reasons. Absence of a clear and documented livestock breeding policy except attempts to develop small ruminant breeding guidelines in the regional states to some extent (Getachew et al., 2016) is the premier reason. Very little consideration of the needs, perceptions and indigenous practices of the farmers and their limited or no participation from planning to execution of the breeding programs is also another reason (Gizaw et al., 2013). In developing countries like Ethiopia, acceptance of new breeds is influenced not only by their productive performances but also by non-production traits like coat color, tail type, horn and ear size and appearance of the animal (Ndumu et al., 2008) and cultural values (Leroy et al., 2015). Absence of effective strategies to sustain the crossbreeding programs at the research centers, at community and household level (Gizaw et al., 2013), mismatch between the genotypes and the environment (Getachew et al., 2015), indiscriminate and unplanned distribution of the improved genotypes and their incompatibility with the farmers' breeding objectives, poor management and low input production systems were also among the reasons for the failure of small ruminant crossbreeding programs in Ethiopia (Gizaw et al., 2013).

Therefore, in order to maximize the benefits that will be obtained from small ruminant crossbreeding programs in the future, the previous recorded achievements should be strengthened and the gaps identified so far must be addressed and filled before the introduction of any exotic breed for crossbreeding. Moreover, lessons should be learnt from the already implemented yet unsuccessful crossbreeding programs, the adaptive features of indigenous small ruminants have to be conserved and the on-farm management must be improved for a better productivity since the indigenous small ruminants have good growth and reproduction performance under on-station conditions indicating their potential. Moreover, the quick fix short cut solution through crossbreeding may be a recipe for genetic progress but such attempts may endanger the adapted indigenous animal genetic resources in the face of climate change. Instead, genetic progress could be achieved through designing a sustainable within breed selection program such as nucleus-based or community-based selection for moderately heritable traits like body weight gain and milk production.

Small ruminant nucleus-based selection programs in Ethiopia

Nucleus-based small ruminant selection programs in Ethiopia, in which flocks were maintained exclusively in agricultural research centers, were mainly employed on sheep breeds like Afar, black head Somali (BHS), Horro,

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Menz, and Washera (Haile et al., 2011; Gizaw et al., 2013). To this end, Werer research center was working on Afar and BHS sheep breeds whereas Bako, Debre Berhan and Andasa research centers applied the program on Horro, Menz and Washera breeds, respectively. The selection criteria were post-weaning growth rates (for Afar and BHS sheep breeds), Pre-weaning weight gain and litter size (for Washera sheep breed) and yearling weights (for Horro and Menz sheep breeds) (Gizaw et al., 2013). Nevertheless, similar to other developing countries with large livestock population, genetic improvement of indigenous breeds in Ethiopia through nucleus-based selection is generally considered too slow and most of the selection programs, except the Menz program, yielded unsatisfactory results (Abegaz et al., 2000). For instance, the Horro nucleus-based selection program shows no progress and the nucleus flock did not result in appreciable genetic improvement (Abegaz et al., 2000; Temesgen, 2010). Moreover, the results of the Afar and BHS programs also remain unreported and the Washera program is yet to be evaluated.

Hence, the selection programs were discontinued, with whatever genetic improvement achieved being lost with the disposal of the flocks. Fortunately, the Washera and Afar breeding programs were re-initiated with new flocks in 2004 and 2011, respectively (Gizaw et al., 2013). Moreover, an elite nucleus flock of Menz sheep has been established with genetic superiority in yearling weight of about 7 kg above the average, and improved rams are being disseminated to village flocks (Gizaw et al., 2011). This may be due to the fact that the Menz sheep genetic improvement is carried out in a controlled environment at the nucleus centers with advanced selection tools such as the best linear unbiased prediction (BLUP) (Gizaw and Getachew, 2009).

Lack of documented selection procedures, high turnover of breeders managing the nucleus flocks, lack of skilled manpower in quantitative genetics particularly the accurate estimation of breeding values, budgetary constraints, lack of vision and commitment from researchers, and bias in the livestock development strategy towards crossbreeding with less emphasis on selection programs could be the possible reasons for the failure of many of the nucleus-based selection programs (Gizaw et al., 2013). Moreover, the farmers were not fully engaged in the selection program, thus their preferences were not fully addressed (Gizaw et al., 2011) and the different intangible, socio-economic and cultural roles that small ruminants could play were not considered (Wollny, 2003; Kosgey, 2004; Kosgey et al., 2006; Kosgey and Okeyo, 2007). A new approach was therefore required and attempts have been made to transform the conventional nucleus-based selection approach into a sustainable participatory breeding program (Haile et al., 2011). One such approach that has recently stimulated global interest is community-based breeding program.

Community based small ruminant breeding programs in Ethiopia

Failure of the crossbreeding and nucleus-based selection programs initiated the development of participatory breeding program called community based breeding program, CBBP (Mueller, 2006; Gizaw et al., 2011; Haile et al., 2011). It is a village based breeding activity planned, designed, and implemented by smallholder farmers, either individually or in cooperatives, to effect genetic improvement in their flocks and conserve indigenous genetic resources. The program would be coordinated and assisted by stakeholders like development and research experts in government and non-government institutions (Gizaw et al., 2013). Unlike the conventional crossbreeding and nucleus-based selection, CBBP involves the local community at every stage (from planning to operation) and takes their indigenous knowledge of breeding practices and objectives in to account. Moreover, it considers the production system in a holistic manner and is a recently advocated option for tropical countries like Ethiopia characterized by low input traditional livestock production system (Solkner-Rollefson, 2003; Baker and Gray, 2004; Wurzinger et al., 2011).

Solomon (2014) documented the summarized advantages of the small ruminant CBBP as follows: the breeding flocks are located within the production environment and potential genotype-environment interactions are therefore minimized, direct participation of farmers is possible and accordingly they could have a sense of responsibility for the targeted breed, the farmers are owners of the initiative and benefits from it, keeping the targeted breed is economically important, utilization of available feed resources is possible, maintenance is labor-intensive and not capital intensive and the initiative is self-administered by the community, but is supported by government and other organizations.

In order to design an appropriate and feasible small ruminant CBBP, the basic steps involve selection of the communities and breeds, analysis of production system (including livelihood strategies), characterization (phenotypic and molecular) of the breeds, definition of the breeding objectives and evaluation of the breeding programs (Kosgey et al, 2006; Haile et al., 2011). However, designing and implementing a sustainable CBBP that would benefit the owners of the small ruminants and the national economy at large is not an easy task, rather it is demanding and worthwhile (Wurzinger et al., 2011). In Ethiopia, attempts were made to develop effective and sustainable community-based small ruminant breeding programs as early as 2003 with Washera and later with

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Gumz sheep (Amhara region agricultural research institute (ARARI) research directory), but failed due to lack of proper knowledge among researchers on the new approach (Gizaw et al., 2013).

Very recently, different community based sheep breeding programs were implemented in Ethiopia by the national agricultural research centers (Bako, Bonga, Debre Berhan, and Worer), in collaboration with the international research institutions (ICARDA-ILRI-BOKU) (Gutu et al., 2015) in four sites (Horro, Bonga, Menz and Afar) and detailed (Gemeda, 2011; Haile et al., 2011; Mirkena, 2011). Unfortunately, the Afar community based sheep breeding program was not successful. On the other hand, the more successful breeding programs in Bonga, Horro and Menz were scaled-out in to two new sheep sites (Doyogana and Atsbi) and one goat breeding site (Abergelle goats) (Solomon, 2014; Gutu et al., 2015). In 2015, the community based breeding programs in Bonga, Horro and Menz were evaluated and realized several achievements (Gutu et al., 2015).

The following were some of the major achievements of the community based sheep breeding programs in Bonga, Horro and Menz: body weights at birth, 3 and 6 months of age and the number of births were increased and thus the market outlet was improved, lambs with bigger size and attractive color were obtained and fetch a better market price, the mortality rates were reduced due to the combination of breeding with improved health care and feeding, better awareness about inbreeding and the need for breeding rams were created and well-functioning cooperatives were formed. In addition, the negative selection, exercised by the local community, has been reverted as fast growing lambs are being retained for breeding purpose instead of ending up in markets. In general, the overall performance of sheep and goats was improved and there was commercialization of breeding rams and bucks (Haile et al., 2011; Gizaw et al., 2013; Gutu et al., 2015). Farmers, who were involved in Menz community-based sheep breeding program and invited to participate in the workshop and field visit held on January 15, 2014, also evidently mentioned that they are benefiting from the community based pure breeding program and explained the adaptation problems of the already introduced exotic breeds (Getachew et al., 2016).

Despite the achievements, the programs had been constrained by several challenges. The challenges include, but not limited to: disease prevalence, feed shortage, poor access to market, selling of selected breeding males, poor cooperation with district extension system, delaying selection of breeding males and mating of females by unselected males (Gutu et al., 2015). Alleviating these challenges and sustainably supporting the programs necessitates the development of operational mechanisms. One such mechanism would be creating a strong link between the programs and the nearby higher education institutes and research centers. Hence, the institutes and the research centers would maximize genetic gains in the breeding programs through their research and community service endeavors. The financial, social and economic feasibility of the breeding programs should also be assessed. The successful community based sheep breeding programs in Bonga, Horro and Menz areas would serve as a model to design and implement similar breeding programs for other breeds. The reasons for the fruitless ending of the Afar community based sheep breeding program should also be pinpointed in order to learn lessons from the failure and revisit the program.

CONCLUSIONS AND RECOMMENDATIONS

Small ruminants in Ethiopia are raised in two major production systems: mixed crop-livestock and pastoral/agro-pastoral production systems. To date, the country has more than 60 million heads of sheep and goats playing a crucial role in terms of meat, milk, income, manure, wool and saving. The existing populations are adapted to the prevailing harsh environmental situation which is characterized by low levels of input and technologies, feed scarcity and disease challenge. However, there is a belief that the productivity of indigenous breeds is very low and they are unlikely to satisfy the fast growing demand for meat and milk that is created due to rapid human population growth, urbanization and increased income. Crossbreeding, nucleus-based selection and community-based breeding programs were the different options implemented in Ethiopia to improve the productive performance of local breeds. Due to its quick benefits, as the result of breed complementarity and heterotic effects, crossbreeding was applied in Ethiopia in the past seven decades. However, the smallholder farmers did not benefit more from the crossbred genotypes than the indigenous breeds and hence most of the crossbreeding programs were failed. Failure of the crossbreeding programs gave rise to the development of nucleus-based selection. But, the selection programs in many nucleus centers exclusively focused on sheep. Moreover, the genetic improvement through such selection programs was too slow and yielded unsatisfactory results. To curve the situation, community based breeding program (CBBP) was introduced and implemented in Afar, Atsbi, Bonga, Doyogana, Horro and Menz areas on sheep and Abergelle goats. The program had a promising start and by now it realized several achievements, though constrained by various challenges. CBBP is therefore a viable option for developing countries like Ethiopia characterized by low input traditional production systems and breeding objectives. However, long-term commitment of all stakeholders is vital as successful and tangible results of the program will only be achievable

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after several generations and many years of consistent collaboration among the key actors. In addition, the program should be part of the national livestock breeding policy.

DECLARATIONS

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Ethics approval and consent to participate

The review paper meets all applicable standards with regard to ethics and integrity. As a researcher and educator in animal breeding and genetics and along with the co-author, the paper has been submitted with full responsibility, following due ethical procedure, and there is no duplicate publication, fraud or plagiarism.

Authors' contributions

Mr. Oumer Sheriff drafted and organized the manuscript while Dr. Kefyalew Alemayehu participated in coordination and helped to draft the manuscript. Both the authors read and approved the final manuscript.

Acknowledgement

The first author gratefully acknowledges the Federal Ministry of Education, Ethiopia, Assosa and Bahir Dar Universities for the PhD fellowship award.

Consent to publish

Not applicable

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Funding

Not applicable

Competing interest

The authors declare that they have no competing interests

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2018 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 8, Issue 3: 74-83; May 25, 2018

ISSN 2228-7701

OMEGA-3 ENRICHMENT OF BROILER DARK MEAT: REDUCING UNLIKE FATS AND FISHY TAINT FOR CONSUMER ACCEPTANCE

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Supporting Information

RESEARCH ARTICLE

PII: S222877011800010-8

Received: January 10, 2018

Revised: May 25, 2018

ABSTRACT: Fish oil (FO) rich in the long chain n-3 polyunsaturated fatty acid (LC n-3 PUFAs) such as eicosapentaenoic acid (EPA, C22:5 n-3) and docosahexaenoic acid (DHA, C22:6 n-3) play substantial roles to improve FA composition and enhance health-related effects of animal products like meat, dairy and eggs. However, optimization based solely on omega-3 enrichment could lead to undesirable odours in animal-source foods, unless the FO withdrawal period is applied for 1 week before slaughter. The aim of study was to investigate whether the replacement of FO with poultry fat (PF) in the diet for 21 days followed by its withdrawal for 1 week affected fishy taint of thigh meat, cholesterol (CHOL) and triglycerides (TG) concentrations, n-3-enrichment and growth rate of male broiler chickens. Two hundred and forty birds (21-day-old, Ross 308) were fed 1 of 4 dietary groups (T1=3%PF, T2=2%PF+1%FO, T3=1%PF+2%FO, T4=3%FO) during a 21-d growth period. Broilers fed dietary fish oil indicated an improved rate of growth ($P<0.01$) plus a decline of the CHOL and TG levels as well as the n-6: n-3 ratio in thigh meat. Moreover, amount of LC n-3 PUFAs especially EPA and DHA were increased and hence a lower monounsaturated FA: PUFA ratio was detected on day 42 and also after oil/fat withdrawal from the diet. The juiciness and tenderness of dark meat of broilers fed FO dietary groups were raised. But the fishy taint was unfavorably higher ($P<0.01$) especially in T4 meat that affected flavor and acceptability thereof. The dissatisfaction of the panelists toward cooked samples of T4 scored as neither like acceptable and their satisfaction with group 3 meats scored as good. Since the lowest n-6/n-3 FAs and a good growth rate were also observed for 1%PF+2%FO (T3), group 3 meats were selected as good-quality omega-3 enriched broiler meat. It is concluded that pre-slaughter withdrawal of replaced fish oil in broiler diet seems ensure the good performance, n-3 enrichment of thigh without probable off-flavors or unlike fats (CHOL and TG) of dark meat.

Keywords: Broiler, Fish oil, Fatty acids, Cholesterol, Thigh meat, Sensory quality

INTRODUCTION

Chicken as the most common type of poultry is well known as an appropriate model in lipid nutrition studies. Birds fed diets with the same nutritive values and rations containing fat, present better performance and the carcass than birds fed diets without fat. Moreover, the performance of animal is depended on their health and a healthy immune system (Das, 2002). In recent decade, fish oil known as one of the stronger source of long chain n-3 PUFAs such as alpha-linolenic acid (ALA, C18:3n-3,), eicosapentaenoic acid (EPA, C22:5 n-3) and docosahexaenoic acid (DHA, C22:6n-3), play substantial role to decrease n-6: n-3 PUFAs ratio and enhance health-related effects of milk, meat and eggs (Connor, 2002; Kris-Etherton et al., 2004; Rymer and Givens, 2005; Schreiner et al., 2005; Yanovych et al., 2013).

Poultry fat is also known as a potential and more economical energy source in feed formulation without detrimental effects and enriched in linoleic acid (LA), omega-6 and omega-9 fatty acid (Baião and Lara, 2005; Panneerselvam et al., 2011). Saleh et al. (2009) stated that a competitive interdependence between n-6 and n-3 fatty acids and keeping the balance between products of their conversion in an organism result from the mutual relation between linoleic and alpha-linolenic acids in dietary fats. Results showed that an unbalanced ratio from the content of n-3 and n-6 PUFAs standpoint might be one of the causes of cardiovascular and ischemic heart diseases with effect on phospholipids of biological membranes (Frenoux et al., 2001). Dietary saturated and trans fats are the primary culprit in today's society leading to worsening of the lipid profile and increasing the risk of heart disease, especially associated with child health development (American Heart Association, 1988).

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In view of the recent findings, the effects of different dietary combinations of PUFAs sources on fatty acids composition in poultry meat (white *vs*. dark cuts), have been analyzed (Zanini et al., 2004). Among five well-known sources of polyunsaturated oils (soybean, canola, sunflower, linseed, and fish), canola oil and fish oil were more successful in reducing unlike fats and improving fatty acid composition of the thigh meat. Among n-3 fatty acids, EPA and DHA have attracted particular attention. In a number of clinical studies, these compounds were shown to reduce the risk of several chronic diseases and their best-evidenced beneficial role, are in cardiovascular disease (Kris-Etherton et al., 2004; Kidd, 2004; Lopez-Garcia et al., 2005).

Currently the main objective of the broiler industry is the production of saleable chicken meat. The industry tries to produce poultry products with a lower cholesterol and triglyceride levels and rich in LC n-3 FAs being studied (Schreiner et al., 2005, Koreleski and Świątkiewicz, 2006). To this end, it is important to limit a minimum number of the negative parameters of meat product such as unlike fats and also to maximize n-3-enriched meat yield and its quality attributes (Bou et al., 2004; Villaverde et al., 2006).

Poultry meat is a desirable component of the human diet, not only the amount but each types of breast and thighs and especially the sensory quality of meat have a great importance for the producers and the consumers. Because the enrichment of poultry meat with PUFAs results in development of undesirable odours "fishy taints" (Betti et al., 2009, Zuidhof et al., 2009) and a more technical way to improve the sensory characteristics of meat of birds fed fish oil is necessary to remove these components from the feeding mixture. Therefore, an optimization based solely on n-3 PUFAs enrichment in chicken meat could lead to lower meat quality attributes (Bou et al., 2004; Zelenka et al., 2008), unless the plans like the dietary fat substitution (Lopez-Ferrer et al., 1999), antioxidant implementation (Lopez-Ferrer et al., 1999; Zanini et al., 2004), and the dietary fat withdrawal for at least 5 days (Betti et al., 2009; Zuidhof et al., 2009) or one week (Aghaei et al., 2012) are applied.

In the present study we aimed to minimize the effects of off-flavors on the sensory quality of FO enriched broiler dark meat, by two technical methods including 1) dietary supplementation with a mixed fat of fish oil and poultry fat and 2) applying a FO withdrawal period for 1 week before slaughter. Therefore the main aim was to investigate whether the replacement of FO with poultry fat (PF) in the diet for 21 days followed by its withdrawal for 1 week affected fishy taint of thigh meat, cholesterol (CHOL) and triglycerides (TG) concentrations, n-3-enrichment and growth rate of male broiler chickens.

MATERIAL AND METHODS

Animal and diets

A total of 600 broiler chickens (Ross 308) obtained from a commercial hatchery (Sefidan Morgh Co., Tabriz, Iran) and fed a same starter diet, up to 3rd wk of age. Two hundred and forty male chickens were separated, individually weighed and randomly assigned on four groups and five replicates (20 floor pens of 1.5 × 1.5 meters, 12 birds per pen). The experimental diets were supplemented with poultry fat (PF) or fish oil (FO) at 3% of feed, as replacement, that formulated in accordance with the NRC (National Research Council, 1994). Both grower and withdrawal plan diets fortified with antioxidants (vitamins E and A). Ingredient composition and nutrient calculation for diets are shown in Table 1. Fish oil (*Clupeonella oil*) and PF were obtained from Iranian sources (Mehregan Khazer Co., Bander Abbass, Iran) and was stored at 4°C before being mixed with other ingredients. The analytical results of fatty acid composition for supplemented PF and FO are shown in Table 2.

Housing and measurement

The experimental treatments were consisted of 3% PF (T1), 2% PF + 1% FO (T2), 1% PF + 2% FO (T3), or 3% FO (T4), and fed to birds from 21 to 42 days of age. The chicks maintained on a 24-h constant lighting schedule (at ~20 lux) with average relative humidity of 60–65%. Both diets and fresh water offered *ad libitum* to birds. Male chickens were individually weighed every week and only the body weight (BW) presented as growth performance at the end of each week of a 21-d growth period. The mean BW, using the pen as the experimental unit at the beginning of the experiment (day 21), were not significantly different (P>0.05). In day 21, 3% fat was withdrawn from the diets to avoid any organoleptic problems that might adversely affect the meat quality, as all birds fed on a commercial finisher diet (withdrawal plan diet). Fifteen birds per group (3 observations per pen) were slaughtered and eviscerated during 6 h and after a 12 h feed withdrawal period and the carcasses were apportioned by hand into commercial cuts and the breasts and thighs, with skin, were separated, packed in plastics bags and chilled during transportation to the laboratory and the samples were frozen in a deep freezer at −20°C until analyze proceed, according to work of Lo´pez-Ferrer et al. (2001). Values in Tables are means of eight observations per treatment and their standard errors. All stored briskets and thighs (remained from fifteen carcasses) used for sensory quality assay.

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Table 1 - Ingredient composition and nutrient content of the experimental diets

Feedstuffs (%)	Starter diet	Experimental diet[1]	Withdrawal plan diet[2]
Poultry fat/Fish oil[1]	–	3.00	–
Fish meal	4.00	1.00	1.55
Soybean meal	30.50	31.00	20.10
Yellow corn	62.50	61.50	55.50
Wheat	–	–	20.00
Monocalcium phosphate	0.80	–	–
Dicalcium phosphate	–	0.90	–
Bone meal	–	–	0.80
Oyster shell	1.20	1.40	1.00
DL-Methionine	0.30	0.20	0.07
Salt	0.20	0.30	0.23
Vitamin/mineral premix[2]	0.45	0.45	0.45
Coccidiostat	0.05	0.10	0.10
Vitamin E	–	0.10	0.10
Vitamin A	0.10	0.05	0.10
Calculated nutrient content			
ME (kcal/kg)	2,950	3,136	3,020
CP (%)	21.20	19.50	17.11
Calcium (%)	0.32	0.14	0.15
Available P (%)	0.32	0.21	0.23
Lysine (%)	1.22	1.07	0.90
Methionine (%)	0.37	0.31	0.28
Methionine + cysteine (%)	0.65	0.56	0.52

[1]Three percent added fat: T1, control diet = 3% poultry fat (PF); T2 = 1% fish oil (FO) + 2% PF; T3 = 2% FO + 1% PF; T4 = 3% FO. [2]Remove oil for one wk before slaughter (to decrease unacceptable odors). [3]Each kg of premix contained: vitamin A, 9,000,000 IU; vitamin D3, 2,000,000 IU; vitamin B1, 1,800 mg; vitamin B2, 6,600 mg; vitamin B3, 10,000 mg; vitamin B6, 3,000 mg; vitamin B12,15 mg; vitamin E, 18,000 mg; vitamin K3, 2,000 mg; vitamin B9, 1,000 mg; vitamin B5, 30,000 mg; vitamin H2, 100 mg; folic acid, 21 mg; nicotinic acid, 65 mg; biotin, 14 mg; choline chloride, 500,000 mg; Mn, 100,000 mg; Zn, 85,000 mg; Fe, 50,000 mg; Cu, 10,000 mg; I, 1,000 mg; Se, 200 mg. Starter diet fed to birds from 0 to 21 days. ME metabolizable energy. CP= Crude protein.

Table 2 - Selected major fatty acid composition (%) of supplemented fat type [1]

Fatty acid (FA) [3]	Dietary fat/oil % wt/wt of total lipids	
	Poultry fat	Fish oil
C14:0	4.43	7.33
C16:0	25.08	19.61
C18:0	8.36	5.36
C24:0	ND	3.46
∑ Saturated fatty acids (SFAs)	37.87	35.76
C16:1 (n-7, cis-9)	5.31	7.76
C18:1 (n-9, cis-9)	26.84	18.95
C18:1 (n-7, trans-9)	8.01	0.17
C20:1 (n-9, cis-13)	0.20	0.45
∑ Monounsaturated fatty acids (MUFAs)	40.36	27.33
C18:2 (n-6, cis-9,12) (LA)	17.70	3.41
C20:4 (n-6, cis- 5,8,11,14) (AA)	0.40	0.79
C18:3 (n-3, cis-6,9,12) (ALA)	1.70	9.93
C20:5 (n-3, cis-5,8,11,14,17) (EPA)	ND	11.50
C22:6 (n-3, cis-4,7,10,13,16,19) (DHA)	ND	8.30
∑ Polyunsaturated fatty acids (PUFAs)	19.80	34.14
Other fatty acids[3]	1.97	2.77
∑ (n-6)	18.10	4.20
∑ (n-3)	1.70	29.94
n-6: n-3	10.64	0.14

[1]Values are means of 3 determinations. [2]PF= poultry fat, FO= fish oil; FAME, fatty acid methyl ester; ALA, α-linolenic acid; EPA, eicosapentaenoic acid; DPA, docosapentaenoic acid; DHA, docosahexaenoic acid; ND, not detected methyl esters.

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Analytical methods

The consumer panel test carried out by cooking thighs, with the skin, which have frozen in refrigerator at −20°C up to 1 month of storage following Lo´pez-Ferrer et al. (2001). Fifteen consumer panelists to testing thigh meats were selected from department and all had experience in poultry meat sensory analysis. Criteria for selection were: 1) age between 20 to 45 years old, 2) not allergic to chicken, 3) consumption of chicken at least once per week, and 4) willingness to evaluate meat from chickens that fed with experimental diets. Vacuum-packed cooked chicken meats served to the panelists in a professional taste panel including normal smell, flavor, juiciness (water-holding capacity) and tenderness of meat using a 5-point scale ranking following Bou et al. (2004). Random 4-digit numbers identified samples, and all dietary treatments presented to the consumer panelists in one session. They were also, asked to rank the total acceptability of the product using four total scale (very good, good, acceptable, bad).

All the samples sliced with a homogenized blade cutter during 4 minutes. Amount of total lipid extracted from all samples by Folch reagent (Folch et al., 1957). After extraction process, 4-milliliters aliquots from ready samples were transported to commercial kits (Kone Specific, Kone Instruments Corp., Kone commercial kit, Japan), and the CHOL and TG were analyzed by means of Autoanalyzer (ALCYON-300, Autoanalyzer, Abbott, American).

The FA composition of the meat samples were determined by a Gas Chromatography, Dany GC-1000 instrument, (Dany GC-1000, Dani Instruments S.P.A., Rome, Italy) equipped with a flame ionization detector, data processor (DS-1000, Dany. Dani Instruments S.P.A. Rome, Italy), hydrogen generator (GLAIND-2200, Via Regina, Lenn Rome, Italy) and a split-splitless injector. Separation of methyl esters performed on an Altech Econo-Cap (Alltech Econo-Cap., Alltech Association Inc., Deerfield, IL), EC-1000 capillary column (30 m × 0.25 mm i.d., film thickness of 0.25 µm). Methanol, *n*-heptane, diethyl ether, and other chemicals from E. Merck (E. Merck and Co. Inc., Munich, Germany), FA standards (Supelco Inc., Bellefonte, PA), and high-purity helium (99.999%) (Roham Gas Co., Dubai, UAE) obtained commercially. The total lipid fraction extracted according to the method of Folch et al. (1957). To determine FA, approximately 500-mgr of the samples were freeze-dried and extracted with 1 chloroform: 2 methanol (v: v). After vaporization of the solvent, a derivatization reaction was carried out on the remaining residue via the addition of 1 mL of 2 *M* KOH in pure methanol and then vibrated for 1 h at room temperature (25 ± 1°C). The methyl esters were extracted in 0.5 mol of three × *n*-heptanes, and all was injected into the gas chromatograph. The initial column temperature was maintained at 75°C for 1 min and then increased at the rate of 30°C/min to 182°C and held at this temperature for 8 minutes. The temperature was then increased further at 7.5°C/min to 200°C and held for 1 min. Helium was used as the carrier and makeup gases at flow rates of 1.2 and 25 mol/min, respectively. The injector and detector temperatures held at 250 and 260°C, respectively. Injection of the samples done in split less mode.

Statistical analysis

All data from the Chol and TG concentrations and FA composition of tissue analyzed by ANOVA using the GLM procedure of SAS software (2001) which is appropriate for completely randomized design. When significances were detected ($P<0.05$), values were compared post-hoc using the Duncan test. The results expressed as averages and their pooled standard error.

RESULTS AND DISCUSSION

Growth performance

Substituting fish oil with dietary poultry fat affected the bird's body weight toward better yield ($P<0.01$, Table 3). T3 group (1% PF + 2% FO) showed the highest BW, followed by T4 group (3% FO). In the present analyses, FO had higher levels of unsaturated FA in compared to the PF. Although, the good performance may be achieved in broiler by FO rich in n-3 FAs (Rymer and Givens, 2005; Villaverde et al., 2006) and capable to reduction of catabolic response induced by immune stimulation and promoting growth (Kris-Etherton et al., 2004; Kidd, 2004), but the sensory losses can be occurred in product (Betti et al., 2009) unless FO removed from diet for 1 wk before slaughter to prevent the development of undesirable odors (fishy taints) in the n-3-enriched meat (Farrell, 1995).

The FA profiles of PF and FO sources

The FA profiles of the supplemental PF and FO are shown in Table 2. The major differences between PF with FO were observed in n-6 methyl esters and n-3 PUFAs especially long chained FAs (C20:5n-3, C22:5 and C22:6n-3). Poultry fat contained 40.36% MUFA, mostly oleic acid (C18:1n9 = 26.84%) and included 18.10% omega-6 PUFA, mainly linoleic acid (C18:2n6, LA = 17.70%). Fish oil included 34.14% PUFA, predominantly alpha-linolenic acid (C18:3n-3, ALA = 9.93%) and LC n-3 PUFA (EPA = 11.50% and DHA = 8.30%). The amount of SFA in PF was slightly

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higher than FO (37.87% in PF and 35.76% in FO). Therefore, the main difference in both fat types was related to n-3 and n-6 FAs contents. However, amount of linoleic acid (LA) in PF than FO was above board higher.

Table 3 - Effect of fish oil and poultry fat on mean body weight in different weeks (g) [1]

Treatments[2]	Age (days)			
	21	28	32	42
T1	753.25	1044.45	1570.22[b]	1920.40[d]
T2	753.42	1054.55	1588.45[b]	1974.55[c]
T3	754.28	1105.82	1606.23[a]	2055.75[a]
T4	756.40	1098.58	1608.25[a]	2028.85[b]
SEM	6.92	9.74	18.92	15.25
Significance [3]	NS	*	**	**

[a-b] Values in the same row and variable with no common superscript differ significantly; [1]Values are means of 5 observations per treatment. [2]T1 = diet with 3% poultry fat (PF); T2 = diet with 2% PF+ 1% fish oil (FO); T3 = diet with 1% PF+ 2% FO and T4 = diet with 3% FO. [3]NS= P>0.05; *= P<0.05; **= P<0.01.

The cholesterol and triglyceride concentrations of thigh meat

Replacement of PF with FO in the diet decreased the CHOL and TG values of thighs muscles, significantly (P<0.05, Table 4). The LC n-3 PUFAs series such as EPA and DHA is capable to reduce the very low-density lipoprotein (VLDL) levels in the blood (Lopez-Garcia et al., 2005). This effect is because of acting to lower the circulating free LDL concentration which is normally delivered to tissues for fat storage or deposited directly in the arteries, and thus reduces the rate of TG synthesis in the liver. It is proved that, the fatty acids within the liver can be utilized for a variety of purposes, from oxidation to the synthesis of structural lipids, but a proportion is re-converted into triacylglycerols, and some of this is stored as lipid droplets within the cytoplasm of the cells like adipocytes or many other cell types including leukocytes, epithelial cells and hepatocytes, especially during infectious, neoplastic and other inflammatory conditions. Excessive accumulation of storage triacylglycerols is associated with fatty liver, insulin resistance and type 2 diabetes (Athenstaedt and Daum, 2006). On the other hand, the lipid classes in broilers unevenly distributed in different marketable cuts, *i.e.* breast or white meat rich in phospholipids, and thigh or dark meat reach in triacylglycerol (Betti et al., 2009).

Table 4 - Triglyceride and cholesterol concentrations of thigh tissues of birds fed with experimental diets [1]

3% fat[2]	Thighs tissues		
	Weight (g)	Cholesterol (mg/100g)	Triglyceride (mg/100g)
T1	360[b]	12.25[a]	19.00[a]
T2	395[a]	9.25[ab]	18.75[a]
T3	390[ab]	7.00[b]	16.25[ab]
T4	384[b]	6.50[b]	11.75[b]
SEM	7.21	1.21	1.80
Significance [3]	*	*	*

[a-d] Values in the same row and variable with no common superscript differ significantly (P<0.05). [1]Values are means of 10 observations per treatment. [2]T1 = diet with 3% poultry fat (PF); T2 = diet with 2% PF+ 1% fish oil (FO); T3 = diet with 1% PF+ 2% FO and T4 = diet with 3% FO. [3]*= P<0.05.

Fatty acids composition of thigh meat

Broilers fed by PF presented higher values of predominant SFA and MUFA than birds fed diet contained FO or FO mixed with PF. From among SFAs, the lignoceric acid (C24:0) increased (P<0.001) in thighs tissues while the amount of oleic acid, a predominant MUFA, not significantly decreased (P = 0.07) by substituting FO in the dietary poultry fat. The linoleic acid (LA, C18:2, a predominant n-6 PUFA), significantly increased (P<0.01) and the highest values was related to birds fed 3% FO (T4). Amount of LA in FO source was almost 5 times less than PF source (3.41 vs. 17.70, respectively; Table 2) while, its amount in thigh tissues was substantially lower (Table 5). All LC n-3 PUFA found to be present at higher levels in thigh meat when the dietary FO was at the highest level. The total n-6 and n-3 PUFA in thigh samples were increased. The SAT: PUFA, MUFA: PUFA and n-6: n-3 ratios were decreased (P<0.01) in thighs meat by replacing PF with FO in the diet.

SFAs and MUFAs

Birds fed PF have higher values of predominant SFA and MUFA than those administered with the FO or both combinatorial PF and FO levels. Indeed, there is a direct deposition of oleic (C18:1, n9) and stearic (C18:0) acids from diet to tissue as well as their endogenous synthesized form in liver to tissue (Lopez-Ferrer et al., 2001). Furthermore, higher palmitic acid (C16:0) content of thigh meat could account for high level of oleic acid in tissue via elongation and desaturation. In the current study, fish oil had lower C16:0 than poultry fat (%19.61 vs. %25.08)

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and it could results (P<0.01) a lower C18:1, n9 in thighs of T4 birds (fed 3% FO) with direct deposition or via endogenous elongation and desaturation processes in the liver. In addition, it is proved that deposition of saturated FAs in tissues is depending on their synthesis in the liver and partly their oxidation rate (Cherian et al., 1996) and FA synthesis's inhibition in the liver is more considered to unsaturated fatty acids than saturated fats (Skrivan et al., 2000). Lo´pez-Ferrer et al. (2001) reported that PUFAs inhibits Δ9-desaturase activity and the formation of MUFA from their precursors. Δ9-desaturase is the key enzyme needed to convert palmitic to palmitoleic acid and stearic to oleic acid (Grønn et al., 1992).

PUFAs

Amounts of linoleic acid (LA, n-6) and α-linolenic acid (ALA, n-3) increased by FO. The highest values were related to EPA and DHA contents and other derivatives of n-3 acids. Also, birds fed solely FO did show better results than those fed on PF + FO (T2 and T3). The n-3 PUFAs contents were almost doubled than the n-6 FAs in the thighs (Table 5). Among n-3 fatty acids, ALA (C18:3) which is available in vegetable oils (mainly flaxseed and canola) and EPA and DHA that are present in fish oils are very important. It is reported that, consumption of ALA can be leading to a significant increase of tissue's EPA, but not DHA; while, dietary fish and fish oils are reported to increase both EPA and DHA in animal tissues (Mantzioris et al., 2000; Burdge et al., 2002). It has been demonstrated by Das (2006) that the ALA and LA are transformed into LC PUFAs and their derivatives by enzymes (Δ6 and Δ5 desaturases and or elongates). These same enzymes metabolize both n-6 and n-3 fatty acids. The fundamental reason for reduction of amount of LA and their derivatives in tissue is because of high levels of LC n-3 PUFAs (mainly, EPA and DHA) in the diet (Hrdinka et al., 1996). On the other hand, the amount of arachidonic acid (C20:4 n6, AA) in tissue of all groups was lower than the predominant n-6 FA (LA); however, a minimum of arachidonic acid might remain constant in tissues to ensure certain metabolic processes (Das, 2006). Researchers reported that, diet supplementation with LC n-3 PUFAs could elevated tissue amount of EPA and DHA with a subsequent reduction in arachidonic acid content within cells of the membrane, especially in the membrane of platelets, erythrocytes, neutrophils, monocytes and liver cells (Boberg et al., 1986; Connor, 2002).

Table 5 - Fatty acid composition of thighs tissue of broilers as influenced by experimental diets[1]

Fatty acid [3]	Experimental diet, % wt/wt of total fatty acid methyl esters[2]					
	Before withdrawal plan (day 42)					
	T1	T2	T3	T4	SE	Sign.[4]
C14:0	1.88	1.78	2.52	2.85	0.378	NS
C16:0	11.06	11.05	11.35	10.92	1.074	NS
C18:0	12.14	11.44	10.56	10.37	0.784	NS
C24:0	0.64^{c}	1.07^{cb}	2.06^{a}	1.65^{ab}	0.204	**
∑ Saturated FAs	25.73	25.11	23.95	25.79	1.252	NS
C16:1 (n-7, cis-9)	2.04	1.59	1.06	1.16	0.371	NS
C18:1 (n-9, cis-9)	27.02	25.98	22.99	21.70	2.117	**
C18:1 (n-7, trans-9)	2.05^{a}	1.37^{ab}	1.27^{cb}	0.58^{c}	0.240	*
C20:1 (n-9, cis-11)	0.37^{b}	0.97^{a}	0.94^{a}	1.29^{a}	0.150	**
∑ Monounsaturated FAs	31.00	28.95	26.82	23.45	0.478	NS
C18:2 (n-6 cis-9,12) (LA)	0.92^{b}	0.94^{b}	1.94^{a}	2.68^{a}	0.312	**
C20:4 (n-6, cis- 5,8,11,14) (AA)	0.77	0.57	0.44	0.80	0.176	NS
∑ (n-6)	2.02^{b}	2.50^{b}	3.33^{b}	4.85^{a}	0.466	**
C18:3 (n-3, cis-6,9,12) (ALA)	0.85^{b}	0.77^{b}	1.14^{b}	2.16^{a}	0.263	*
C20:5 (n-3, cis-5,8,11,14,17) (EPA)	0.10^{c}	1.36^{cb}	2.68^{ab}	3.88^{a}	0.478	***
C22:5 (n-3, cis-7, 10, 13, 16, 19)	0.00^{b}	0.02^{b}	0.06^{ab}	0.29^{a}	0.082	NS
C22:6 (n-3, cis-4,7,10,13,16,19) (DHA)	0.00^{a}	0.15^{b}	0.66^{c}	1.51^{a}	0.127	***
∑ (n-3)	0.95^{c}	2.31^{c}	4.55^{b}	7.64^{a}	0.643	***
∑ Polyunsaturated FAs	2.97^{c}	4.81^{c}	7.88^{b}	12.50^{a}	0.932	***
Sum fatty acids	59.92	58.87	58.65	61.74	2.542	NS
SAT: PUFA	9.63^{a}	6.02^{ab}	3.08^{b}	2.17^{b}	1.300	**
MUFA: PUFA	10.97^{a}	6.06^{b}	3.43^{c}	1.99^{c}	0.787	***
n-6: n-3	3.40^{a}	1.18^{b}	0.77^{b}	0.64^{b}	0.673	*

[a–d] Values in the same row with no common superscript differ significantly. [1]Values represent the means of ten observations per treatment and their standard errors. [2]T1 = diet with 3% poultry fat (PF); T2 = diet with 2% PF+ 1% fish oil (FO); T3 = diet with 1% PF+ 2% FO and T4 = diet with 3% FO. AA=arachidonic acid, ALA=α-linolenic acid, EPA=eicosapentanoic acid, DPA = docosapentaenoic acid, DHA=docosahexanoic acid. Others fatty acids that were not detected. Sign.= * P< 0.05; ** P<0.001; *** P<0.001.

Total FA Ratio

The SAT: PUFA, MUFA: PUFA and n-6: n-3 ratios were reduced (P<0.01) in tissue by replacement of PF with FO in the diet. These findings are in agreement with the results of those that used menhaden-oil-enriched diets

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(Cherian et al., 1996) and replaced or combined FO in diets (Lopez-Ferrer et al., 1999). It is clearly shown in table 5 that FO replacement in dietary fat declined n-6: n-3 ratio and caused omega-3-enriched chicken thigh. A FO-enriched diet could make poultry meat an attractive alternative for those consumers that are not willing to include fish products in their daily diets. Therefore, poultry meat in comparison with an equal sized portion of canned tuna fish could provide between 2.7 and 3.5 times more n-3 PUFA per edible portion of breast and thigh meats, respectively (Sinclair et al., 1998). In addition, an omega-3-enriched meat known to healthy product might guarantee a notable decline of the cholesterol and triglyceride levels that are linked to the total fatty acid ratios or their saturation and unsaturation types.

Omega-3 enrichment of broiler dark meat

Regarding International Life Sciences Institute (1995) recommendations in the human daily requirements to LC n-3 PUFA, serving of 200 g of chicken thigh meat fed on 3% FO diet, would provide approximately 160 mg of EPA and 1.100 mg of total n-3 FA. In the current experiment, 117 mg of ALA, 271.87 mg of EPA and 69.75 mg of DHA would provide from total n-3 in 200 g of thigh meat of T3-fed chicks (Figure 1). The real n-3 enrichment of meat could therefore accomplish by marine origins like FO rich in LC n-3 PUFA; however, it is highly susceptible to oxidative process and may harm human health. Vitamin E is well-known as a good defender against lipid oxidation (Morrissey et al., 1998). Hence, for adjustment of human lipid metabolism with a high EPA content of n-3-enriched broiler meats, fortifying the diet with antioxidants like vitamin E levels, e.g. 100 IU in broiler diets - relatively high levels can be fed- is necessary (Surai and Spark, 2000). Otherwise, EPA and DHA contents in meat could be limited and off-flavors could occur. Consequently, diets enriched with n-3 PUFA and low or non-vitamin E may exacerbate the formation of reactive oxygen species in chicken breast muscle that could create from the reaction of unsaturated fatty acids with transition metals such as iron oxidation (Morrissey et al., 1998).

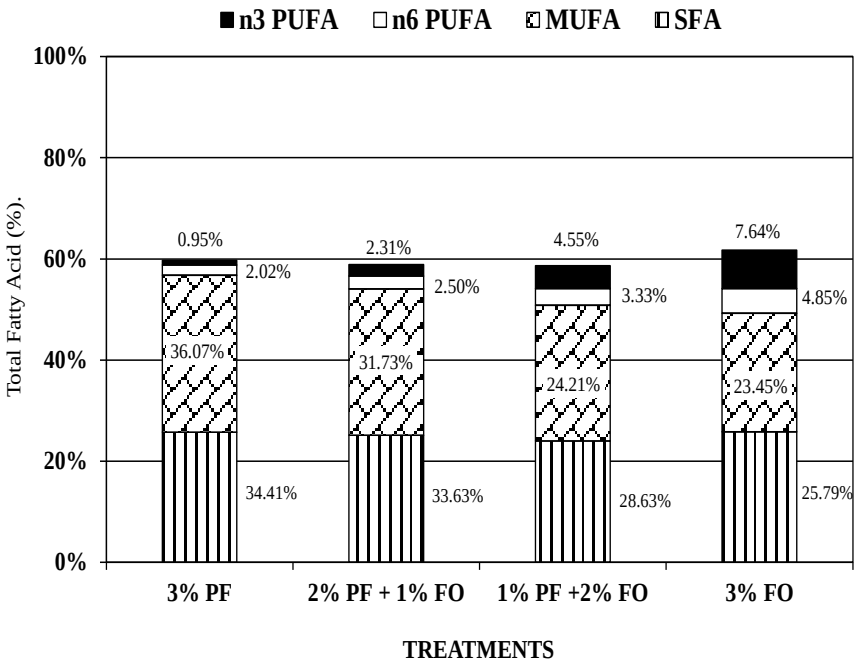

Figure 1 - Fatty acid composition of thighs meat of male broiler fed from 3% fat. Values of figures are correspondent to those shown in Table 4. PF= poultry fat, FO= fish oil; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids. T1=3% PF; T2= 2% PF + 1% FO; T3= 1% PF + 2% FO; T4= 3% FO.

Sensory evaluation of omega-3 enriched dark meats

Table 6 is shown panel test results. The sensory quality parameters of thigh meat such as flavor and normal smell of chickens fed on solely 3% FO (T4) did significantly ($P<0.01$) show lower scores (2.73 and 2.35, respectively) after 1 month of storage, but the juiciness and tenderness were acceptable (4.20 and 3.86, respectively). The consumer's acceptance of T2 and T3-cooked thighs were better than T4. Average consumer's acceptance ratings for treatment 3 (1% PF + 2% FO) ranged from 3 to 7, which correspond to a score of "neither like acceptable" to "like good." Consumers commented that thigh samples had more aftertastes which are probably attributable to the greater occurrence of fat-associated flavor volatiles in dark meat (Betti et al., 2009). The highest n-3 FAs content, lowest CHOL and TG levels and a good growth rate were achieved in this group 4 broilers who received omega-3

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enriched and Vit-E fortified diet after 1 week withdrawal plan, but panelists were reported the serious sensory losses for T4 cooked meats that couldn't satisfied panelists while, T3 samples presented most advantages with good flavor. In n-3-meat enrichment method of Lo´pez-Ferrer et al. (2001), withdrawal design (use of 4% FO for 3 or 4 week, followed by a mixture of 3% linseed oil and 1% FO) was more efficient than n-3-enrichment with 2% FO throughout the experimental period. By their method, higher EPA, DPA, and DHA levels in tissues as well as improved organoleptic quality of enriched meat were detected.

In present study, all factors including loss of water holding capacity, tenderness, and flavor need to take into consideration to evaluate the overall quality of n-3 PUFA enriched products for commercialization. Hence, optimization based solely on origins rich in n-3 PUFA enrichment in chicken meat could lead to lower meat quality attributes. Regarding to our findings and current information, such strategies like the incorporation of FO in the diet for 21 d followed by its withdrawal for 1 week before slaughter, may be a preferable option to exploit enriched meats especially thighs that need a shorter time to enrichment with the greater fat content. The study of n-3-enriched thighs meat underlying the effects of vitamin E inclusion and fish oil withdrawal can facilitate a better understanding of the changes that occur in dark tissues following reuse or *de novo* synthesis in the liver or tissue.

Table 6 - Consumer panelists and acceptability scores of cooked thigh meats after 1 month of storage at - 4°C according to different of fish oil in diets[1]

Experimental diets [2] / Thigh meat	T1	T2	T3	T4	SEM	Sig.[3]
Flavor	4.13 [b]	4.25 [a]	3.93 [c]	2.73 [d]	0.152	***
Normal smell	3.40 [b]	3.86 [a]	3.24 [b]	2.35 [c]	0.146	***
Juiciness	3.53 [c]	3.73 [ba]	3.93 [b]	4.20 [a]	0.161	*
Tenderness	3.60	3.70	3.73	3.86	0.174	NS
Acceptability	7.80 [a]	7.10 [b]	6.20 [c]	4.40 [d]	0.447	***

[a–d] Values in the same row and variable with no common superscript differ significantly. [1]Values are means of 15 observations (for professional taste panel and acceptability) per treatment. At 1 month of storage a freshly cooked commercial chicken meat sample stored for 1 d at −20°C (vacuum packed) was added to the consumer test as a blind control. The consumers ranked flavor, normal smell, juiciness and tenderness of meat using a 5-point scale and the acceptability of the meats using a 9-point scale (1 = bad; 3= acceptable; 6= good; 9 = very good). Juiciness = Water-holding capacity. [2]T1=3% PF; T2= 2% PF + 1% FO; T3= 1% PF + 2% FO; T4= 3% FO. [3]Sign.= *= P<0.05; **= P<0.01; NS= P>0.05.

CONCLUSIONS AND RECOMMENDATIONS

Diet supplementation with fish oil resulted in better n-3 enriched dark meat with lower unlike fats especially in groups 4 and 3 birds, respectively. But based on the dissatisfaction of the panelists toward T4 meats and satisfaction with cooked T3 samples (scored as good), the meat of group 3 animals fed 1%PF + 2%FO was selected as good quality n-3-enriched thigh meats. This study showed that meat enrichment based solely on FO rich in n-3 PUFA couldn't lead to reduction of meat quality detriments, while diet supplementation with combinatorial fish oil and poultry fat with adequate antioxidant for grower period by applying 1 week withdrawal plan could appropriately reduce sensory quality losses. Also, the meat of group 3 (1% PF + 2% FO) seems to be a good combinative fat for supplementation in broiler diets to reach a good growth rate for n-3 enriched dark meat product. Regarding to meat enrichment strategies of broiler chickens, the roles of the physiological mechanism of the FA deposition and vitamin E in the oxidative stability of LC n-3 PUFA sources to remove sensory losses, are substantial for produce health promoting nutritionally products, which are preferable scopes.

DECLARATIONS

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Ethical approval

The review board and ethics committee of *Department of Animal Science, Shabestar Islamic Azad University* approved the study protocol.

Authors' contributions

SCh and HA participated in the design of study and performed the experiments. SCh analyzed the data, wrote and revised the manuscript for important intellectual contents. Both authors read and approved the final manuscript.

Acknowledgements

The support of Islamic Azad University, Shabestar Branch gratefully acknowledged. The manuscript was summarized from the project (grant no. 19550101842006). The authors would also like to especially thank Dr. A.M. Vatankhah and Vahid Chekaniazar for valuable support and the skilled technical assistances throughout the experimental analyses.

Competing interests

The authors declare that they have no competing interests.

Consent to publish

Not applicable

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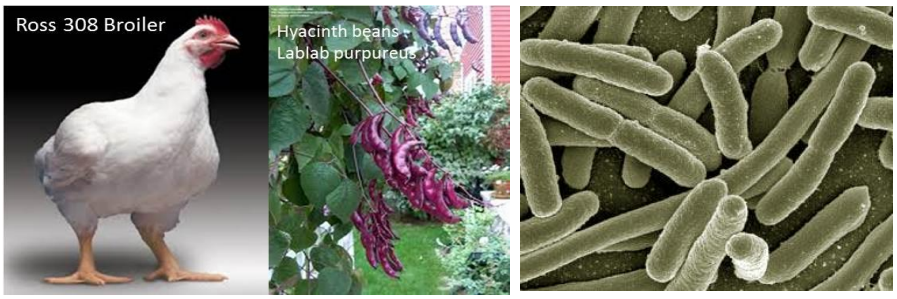

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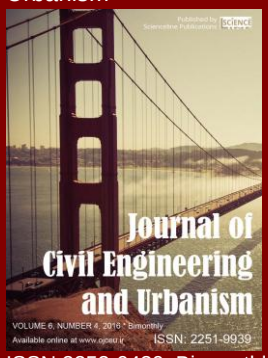

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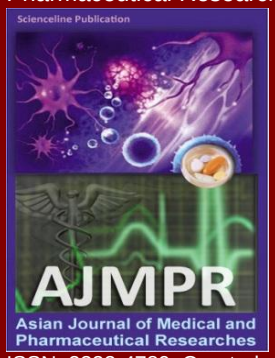

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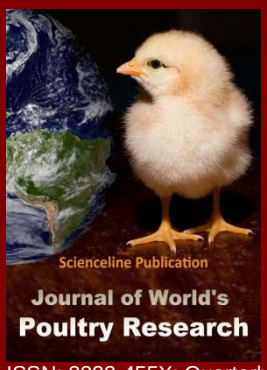

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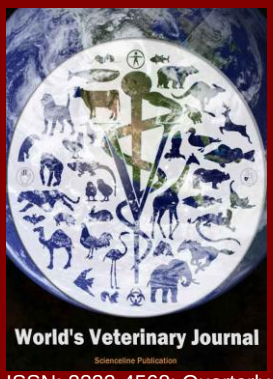

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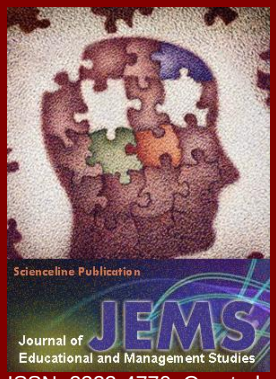

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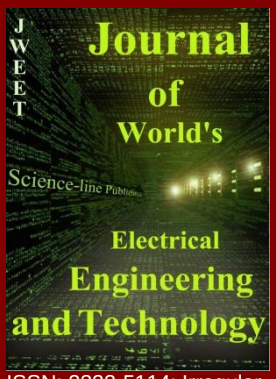

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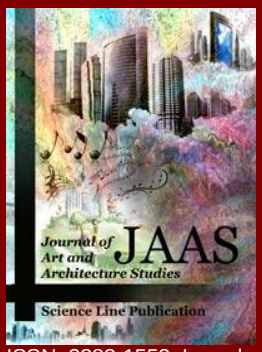

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