Major Factors Affecting Hide and Skin Production, Quality and the Tanning Industry in Ethiopia

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Abstract: Ethiopia has 55.03 million cattle, 27.35 million sheep and 28.16 million of goats. This places the country as one of the richest countries in livestock resources. For instance, its potential for production of hide and skins was estimated at 3.78 million cattle hides, 8.41 million sheep skins and 8.42 million goat skins in 2012/13. Currently 27 tanneries in Ethiopia produce all forms of hides and skins and finished leather for the domestic and export markets. Ethiopian hide and skin have good reputations in the international leather market for their unique natural substances. This raw material of the leather industry is mainly derived from local areas of the country where basic amenities for slaughtering and subsequent marketing are either not in existence or lacking. Despite the production potential of hides and skins, the leather industry is still constrained by the poor quality of raw materials, lack of an efficient market structure, a weak extension service, competition from local/rural tanning industries and a lack of price incentive for production of good quality raw material. Tanneries state that only 10 to 15% of harvested skins qualify for top grades, with the rest downgraded and rejected mainly due to deterioration of skin quality owing to skin diseases and various defects.

Key words: Defect • Ectoparasite • Market chain • Microbial infection

INTRODUCTION

Archeological studies have shown that hide and skins have been used since antiquity as clothes, vessels, bedding and possibly structurally in ancient dwelling places. At present leather is used in various applications. According to [1], skin of cattle, camels, horses and buffaloes are called hide and that of sheep and goat is known as skin. Hides and skins, raw materials for the tanning industry, are renewable and easily perishable resources and their production is dependent on the rearing, management and disposal of the livestock population. The availability of skins through slaughtering or death of livestock is of particular importance to the leather industry [2].

On a world scale, significant amount of sheep and lamb skins originate predominantly in China, New Zealand, Australia, the Near East and the EU. Globally, approximately 6.0 million tonnes of raw hides on a wet salted basis were processed to yield about 522600 tonnes of heavy leather and about 12759 million square feet of light leather, including split leather. In comparison, Europe produced about 71700 tonnes of heavy leather and about 2473 million square feet of light leather. For goat and sheep worldwide 646800 tonnes of raw skins on a dry basis were converted into almost 4716 million square feet of sheep and goat leather [3].

The livestock population of Ethiopia is estimated to be 55 million cattle, 27 million sheep and 28 million of goats [4]. This places the country as one of the richest countries in livestock resources. It has a huge potential for production of hide and skins. For instance, its potential was estimated at 3.78 million cattle hides, 8.41 million sheep skins and 8.42 million goat skins in 2012/13 [5]. Ethiopia’s agriculture sector contributes between 45-50 % of the country’s total GDP in the 2010-11 fiscal year, live animals generated USD 148 million of Ethiopia’s foreign exchange, leather and leather products generated USD 104 million and meat and meat products generated USD 63 million, ranking 6th, 8th and 9th respectively.

Ethiopian small ruminant skins, especially sheep skins traditionally have a very good reputation for quality in the world leather market due to their fine grain and compact structure [6]. According to the USAID report, the
existing 27 tanneries in Ethiopia produce all forms of hides and skins and finished leather for the domestic and export markets with average daily soaking capacity of 107,850 pieces of sheep skin, 51,550 pieces of goat skin and 9,800 hide. Meanwhile, the annual capacity reaches an estimated 48 million (32.4 million sheep and 15.5 million goat) skins and 2.9 million hides. However, the capacity to process hides and skins greatly exceeds domestic supply, particularly for raw sheep and goat skins [7].

Although Ethiopia has very good potential to produce substantial quantities of hide and skins, the quality of the hide or skin is to a large extent related to the amount of damage to the grain (or outside) surface. In this regards, the leather industry sector is losing large amount of money due to decline in quality and fall in export price [8,9]. It is estimated that about one quarter to one-third of all the skins processed at tanneries are unsuitable for export due to various defects [10]. Some reports indicated that, the major problem affecting the leather and especially tanning industry is related to skin diseases, scratches, scabs, branding, poor pattern, flay cuts, putrefactions and poor substances [6]. However, to the best of our knowledge little has been said on the contribution of the above-mentioned factors affecting the tanning industry. This review therefore highlights the production and market chain of hide and skin and gives a detailed account of the major factors affecting the hide and skin quality as well as the leather industry in Ethiopia.

**Hide and Skin Production in Ethiopia:** Based on annual off take rates of 7% for cattle, 33% for sheep and 35% for goats, the potential production is estimated at 3.78 million cattle hides, 8.41 million sheep skins and 8.42 million goatskins in 2012/13 [5]. The 7% off-take rate for cattle falls significantly below the African average of 12.71% and the world average of 20.31%. While the off-take for sheep ranks slightly below the average for Africa, the off-take for goat skin ranks slightly higher than the Africa average, though both remain well below the world average [7].

Ethiopian hide and skin have good reputations in the international leather market for their unique natural substance of fitness, cleanness, compactness of texture, thickness, flexibility and strength. The cattle hides, identified as “Zebu type”, are popular for their fine grain pattern and fiber structure that are well suited for the production of quality upper leather. The highland sheep skins known as “hair sheep”/“Selale type” are considered to be the world’s finest and have a highly compacted texture. They are excellent raw material for high quality leather for dresses, gloves, sports gloves and other garments. This unique feature of the Ethiopian sheep skins enables them to fetch higher prices in the international leather market. Goat skins from the highlands are categorized as “bati-genuine” and those from the lowlands as “bati-type” in the international market. “Bati-genuine” is associated with highest quality class goatskins in the world. The particular characteristics of Ethiopian bati-genuine goat skins are their thickness high flexibility and clean inner surface and are known worldwide for being excellent raw material for producing high quality suede leather [11]. This raw material of the leather industry is mainly derived from local areas of the country where basic amenities for slaughtering and subsequent marketing are either not in existence or lacking [12].

**Market Supply of Hides and Skins in Ethiopia:** The marketing of hide and skins starts at the producer/consumer level and passes through a chain of middlemen until it reaches the tanneries (Diagram 1). The collectors of raw hide and skin are available in almost all towns of Ethiopia. They collect the hide and skins from both through rural agents or through farmer’s carriage to market and urban areas through intermediary collectors or themselves. Many of them are indeed long age experience starting from the time of Armens, with the majority of them starting the business in the 1960s [13].
goats (90%) and most of the cattle (70%) are slaughtered informally in homesteads for consumption by the owner or in a small community where no formal slaughtering facilities exist. Generally, these informal slaughtering activities are largely beyond the reach of government considerations [7].

Rural and Urban Slaughter Operators: The operators in rural slaughtering slabs produce a sizable volume of hides and skins, second to the individual household. These operators use poorly equipped slaughter points, where the infrastructure is sometimes a slab of concrete, under a shade or using poles for hoisting carcasses. These operators are normally located in small towns adjacent to butcheries in various trading centers. More than 80 percent of such facilities are established in Oromia (54%) and Amhara Regional State (27%). Such facilities are scattered in rural towns and often without adequate supervision. The tools used in these facilities are usually rudimentary and of inferior qualities causing damage to the hides and skins during flaying/slaughter. Most often, all operations are carried out on the floor. In municipal slaughtering operation cattle hides are recovered by hand from the carcass, causing extensive damage in the form of deep cuts and holes. Cuts and holes reduce the value of a hide or skin. The difference between a machine-flayed hide, which presents no cuts or holes and a hand-flayed hide, with cuts and holes, can reach 20-30% of the hide’s value [7].

Hide and Skin Collectors
Village Level Collectors: The hides and skin from the sources (usually the household across the country) are normally collected by the village level collectors or trader agents. The trader agents collect the raw hides and skin by going door to door in case of urban area and by setting temporary collection point at most accessible spot in case of rural areas [12].

Intermediary Traders/Collectors: The intermediaries frequently act as agents for larger suppliers (wholesalers) based in larger towns and cities. Intermediary traders collect, handle, preserve, store and transport the skins they purchase on behalf of their respective wholesalers. In many cases, however, experts report that both small and intermediate traders/collectors use insufficient amounts of salt and/or an improper grain size, which inadequately preserves hides and lowers their value. The intermediaries usually collect, salt and store skins in their own facilities. They often transport hides/skins in such a way as to minimize cost by optimally matching the quantity shipped with the size of the truck used to transport them [7].

Large Traders/Wholesale Suppliers: These suppliers usually own storage and transport facilities with which they source the raw hides and skins that they then supply to tanneries. These suppliers located in the main town of the woreda, zone and regional city of the country. They receive the raw material from nearby small to medium collectors additionally they have collection point at the main store or near to the weekly market of the district for those fresh hide and skin removed from slaughtered animals in peri-urban and urban producers and consumers [12]. Considering the development potential and economic importance of hides and skins, in the last two to three decades the government has launched different development programs aimed at increasing the supply and improving the quality of the raw material. Even though these, hides, skins and the leather industry are still constrained by the poor quality of raw materials, lack of an efficient market structure, a weak extension service, competition from local/rural tanning industries and a lack of price incentive for production of good quality raw material [14].

Leather Industry in Ethiopia: The emergence of modern tanning in Ethiopia dates back to 1918 and 1927 with the establishment of the then ASCO (currently Addis Tannery) and Darmar /Awash (currently ELICO) tanneries, respectively. Between 1954 and 1976, Dire, Modjo and Kombolcha tanneries were established [15]. The leather industry sector is one of the growing economic sectors in Ethiopia. However, the sector is constrained by different factors like external parasites, inappropriate management of animals, faults during slaughtering and improper handling of skin before reaching to the tannery, the sector is losing large amount of money due to decline in quality and fall in export price [8]. Currently 27 tanneries in Ethiopia produce all forms of hides and skins and finished leather for the domestic and export markets. These tanneries have an average daily soaking capacity of 107,850 pieces of sheep skin, 51,550 pieces of goat skin and 9,800 hide. The annual capacity reaches an estimated at 48 million (32.4 million sheep and 15.5 million goat) skins and 2.9 million hides. Ethiopia’s...
tanneries process only 64% of their installed finishing capacity for skin processing and 63% of the capacity for hides processing, while some tanneries run as low as 30% capacity. This “low supply”/“high demand” of hides and skins creates shortages that often result in a lack of competitiveness among domestic suppliers and produces hides and skins of mediocre quality. Lower quality hides and skins negatively impacts not only tanneries, but also Ethiopian footwear and other leather goods producers who sell their product domestically and abroad. To help ease the shortage of hides and skins, some tanneries have begun to import semi processed hides [7].

Ethiopian tanneries indicated that after 1983 the supply of 1-3 grade raw hides and skin has sharply declined. In this way, the Gojam skin is the best quality skin with more of 1 to 3 ranking, with much of its proportion of best quality and they said they fall under fierce competition to secure the Gojam one [13].

According to data from Ethiopia Ministry of Industry (2012), the leather and leather product exports increased from 67 million USD to 104 million USD between 2004/05 and 2010/11. Due to the financial crisis and other factors, export decline in 2009/10 but picked up heavily in 2010. On average the leather and leather products industry contributed 5.9% to the total export earnings for the year 2004/05-2010/1 corresponding to a slight decline, due to other export items occupying significant positions in the country’s export mix. According to FAO the global trade of light leather was 16.6 billion USD in 2010. Despite its impressive resource base Ethiopia’s share in this trade is about 6%. But trends of the different product categories show the crust, finished leather and shoe exports increased while wet blue and pickle decline. In fact, pickle and wet blue exports ended in 2010 due to the government policy which put heavy taxes on exports of wet blue, pickle and crust in order to encourage production and export of finished leather.

Major Causes of Lower Grade Hide and Skin Quality Production in Ethiopia: The percentage of skins having defects that downgrade quality has increased tremendously in Ethiopia. Skin quality is primarily defined by the absence of damage to the grain layer of the skin [16]. Tanneries state that only 10 to 15% of harvested skins qualify for top grades, with the rest downgraded and rejected. The quality of finished leather is related to a number of surface and structural defects that hide and skin acquire in the life of the animal, during slaughtering, storage and transportation stages [17]. The causes of defects on raw hide and skin can be broadly classified as pre-slaughter defect causes and post-slaughter causes.

Pre-Slaughter Defect Causes

Biological Factors: Breed: The breed and the gender of the animal have an effect on the weight and the strength of the hide [18]. Breed or types of sheep skins show more undesirable breed characteristics than goat skins. The best quality skins are plump or stout and have dense uniform structure and usually have surface areas that are small in proportion to their weight. The small size of skin yielded sheep of tropical and mountain area origin is not considered a drawback because of the skin’s superior quality of high tensile strength, compact fiber structure and excellent grain. But small size skins that are downgraded due to poor quality are unwanted by tanneries [9]. The breed of animal is of course important, the best hides for leather purposes usually coming from those animals which are bred for beef production, i.e. those which develop carcasses with a high proportion of lean meat in a reasonably short time under conditions of economic feeding [19].

Sex/Age: The skins from male goats and sheep will be heavy with a coarse grain. Female skins will have better tensile strength. The skin structure of young animals tends to be fine, compact and have tight grain patterns. As animals grow older, the grain surface becomes tougher and coarser grained. Also with age animals accumulate more scars from brands, diseases, parasites, scratches and other injuries [9].

Management/Environment Related Factors

Mechanical/Branding: Brand mark is a permanent mark applied to the hair/grain side either by a hot or freezing iron type device; location determines hide classification. Branding costs the leather industry large amounts of money due to the wasted portions of the hides. The loss of value is dependent on the placement of the brand. In Ethiopia animal branding is a common practice of livestock owners especially by pastoralists on their animals for identification and to treat their animals from animal diseases; the formed scar greatly affects the tanning industry of the country [12].

Housing and Fencing: The issue of housing and fencing is a management problem and therefore requires appropriate steps to reduce damages to the hide/skin of
an animal. Some of such damages include pricking, scratches, drag marks and dunging. Indeed, these damages affect the grain layer (Leather surface of the corium layer) which after tanning, lowers the quality of leather grades and utility in resultant leather goods processing. In particular, dunging predisposes the hides or skin to microbial action serving as a good medium for microbiological activity eventually destroying the final quality of the leather surface [20]. In a field survey the vast majority of livestock owners used the cultural barn, which is muddy, corrugated and uncomfortable for their animals hence predisposes for different hide and skin defects [12].

Nutrition: Poor nutrition causes an animal to be smaller. It also causes the skin to be thinner and have poorer substance producing leather which lacks elasticity and has a dead feel. On the other hand, fat animals can cause too much fat content in the hide, which prevents curing agents from penetrating the hide [21]. Poor nutrition predisposes the skin to low febrile condition where the weight and final quality of leather is affected irrespective of the subsequent efforts of other condition being optimized. The resulting condition is referred to as “papery leather” which is a common problem experienced in the areas where poor or unavailability of pastures and forbs is eminent.

Climate: The Ethiopian highland sheep skins known as “hair sheep”/“Selale type” are considered to be the world’s finest and have a highly compacted texture. They are excellent raw material for high quality leather for dresses, gloves, sports gloves and other garments. Goatskins from the highlands are categorized as “bati-genuine” and those from the lowlands as “bati-type” in the international market. “Bati-genuine” is associated with highest quality class goatskins in the world [11]. However, majority of cattle and goat population reared in the low land part of the country has low demand by the tanneries due to a variety of reasons [12].

Skin Diseases
Defects Due to External Parasite: A considerable portion of the pre-slaughter defects that accounts for 65% are directly related to skin diseases caused by the ectoparasites; or to the secondary damage that occurs when the animal scratches itself (figure 1) to relief the itching [10].

![Fig. 1: Permanent scar/scratch lesions left on wet blue goat skin in Gelan tannery, Ethiopia. Source (Behailu 2015).](image)

Defects due to external parasitic damage particularly cockle lesions has increased dramatically in the past 10-15 years and is currently holding number one position as cause of skin down grading and rejection in Ethioia [17]. Kassa [10] showed that skin diseases due to external parasites causes 35% of sheep skins and 56% of goat skin rejections in some of Ethiopian tanneries. In addition, [22] reported that, 49.2% of skin from sheep and goats had cockle lesions in some Ethiopian tannery. The same author reported that particularly 76% skin from goats) and 22.4% from sheep were recorded to had cockle lesion. A study conducted by [23] in other tannery of the country showed that 47.1% of sheep skin and 24% of goat skin experienced cockle lesion. The external parasites that has so far been reported to be significantly affecting the tannery industry includes mange (demodectic and sarcoptic), sheep ked, lice and ticks. Tannery owners in Ethiopia complain that, three decades ago, they used to get the best quality (grade1-3) sheep skins over 70% of what they produce, but due to the cockle problem, today it has dwindled to 15%.

Demodectic Mange: Demodex species enters the hair follicles and sebaceous glands producing a chronic inflammation with proliferation and thickening of the epidermis and loss of hair. In Bovine demodicosis the most important effect is the formation of many pea-sized nodules, each containing caseous material and several thousand mites which cause hide damage and economic loss. Though these nodules can be seen in smooth coated animals, they are often undetected in rough coated cattle.
until the hide has been dressed. Demodectic mange is distributed in different agro-ecological zones in Ethiopia, such as in central lowland of Oromiya [24], in midland and highlands of Amhara region [25] and in lowland and midland areas of southern part of the country [26]. In goat’s prevalence rates ranging from 2.83% to 6.8% was reported in different regions of the country [27, 26].

**Sarcoptic Mange:** Sarcoptic scabiei varcaprae and Sarcoptic scabiei varovis have a wide geographic distribution in many goat and sheep rearing in arid and semi-arid areas of Ethiopia and it is more commonly seen in goats than sheep in Ethiopia. They are widely distributed in lowland [26,28] and midlands [24,28] regions of the country.

**Sheep Ked:** Sheep keds are wingless flies brown in color and one of the major parasites that causes cockle skin lesion which are observed in processed skin in tanneries. They are more commonly seen in sheep than goats. Keds suck blood and can cause anemia as well as skin irritation/“Ekek”, an Amharic word for itch. Sheep ked *Melophagus ovinus* is more prevalent in highlands than midlands and no cases yet recorded in lowlands of Ethiopia. The prevalence of “Ekek” (cockle), lesion in *Bovicola ovis* and *Melophagus ovinus* infested groups of sheepskin were 100% and 95%, respectively and causes higher proportion of skins to fall into the lower grades [25]. Ermias [29] unveiled that from the freshly examined sheep pelts 32.7% had *Melophagus ovinus* in Sebeta Tannery.

**Lice:** Two types of lice affect ruminants, biting (chewing) lice and sucking lice. Biting lice are brown in color and mobile. Affect cattle and small ruminants. They feed by chewing on the skin surface and surface debris. Biting lice produce itching, irritation and possible hair loss. Lice infestation in Ethiopia is the most frequently reported and the most important skin disease of ruminants this is because lice are found to be the cause of cockle. In sheep Hailu [30] reported a prevalence rate for *Linognathus* spp (75.5%), *B. ovis* (67.1%), *Linognathus ovillus* (14.6%) and *B. ovis* (36.1%). While the same author reported 28.3% prevalence rate of *Linognathus* species in goats. Lice and keds are considered a major cause of cockle, which is a defect which appears on the grain side of semi-processed and crust leather after pickling that cannot be detected when the skin is examined raw or unprocessed. It results in huge economic loss to tanneries and the country at large since the damage is recognized after a lot of cost incurred on the processing after which the damaged skins have to be rejected or downgraded [31].

**Ticks:** There are numerous types of ticks that affect cattle, sheep and goats in Ethiopia. The penetration of the skin by the piercing mouth parts makes holes which are defects in processed skins; such skins give “ticked” leather, which is of inferior quality. The economic impact of tick infestations is enormous in Ethiopia with a conservative estimate of one million Ethiopian Birr (over 55 thousand USD) loss annually, which was due to rejection and downgrading of hides and skins due to effect of ticks [31].

**Sheep and Goat Pox:** Sheep pox is a viral disease of sheep and goats which is highly contagious. Healing of the skin affected by pox is slow and permanent scars can be left (figure 2). This causes huge economic losses in the tanning sector [9].

**Lumpy Skin Disease (LSD):** It is a viral disease that affects the skin of cattle. The characteristic gross pathological findings are the skin nodules which sometimes are also found in the subcutaneous tissue. The biggest economical loss is the loss of condition and permanent lesions of skin [32]. In Ethiopia, LSD was first observed in 1983 in the north-western part of the country (south-west of Lake Tana). The disease has now spread to almost all regions and agro-ecological zones of the country. Because of the wide distribution of the disease and the size and structure of the cattle population in Ethiopia, it is likely that LSD is one of the most economically important livestock diseases which affect the hide quality in the country [33].

**Dermatophilosis:** It is a contagious skin disease caused by *Dermatophilus congolensis*. The disease is non-pruritic and is characterized by exudative, proliferative or hyperkeratotic dermatitis, accompanied by the production of crusts and folliculitis. The causative organism is an aerobic, gram-positive bacterium that produces motile zoospores; it invades the skin and causes an acute, sub-acute or chronic skin disease. It is a common disease causing suppurative lesions which break out spontaneously or become hardened. These cause blemishes on the superficial grain tissues of the skin.
Transmission is by direct contact or through vehicle example by tick (*Amblyoma varigatum*). It is a cause for down grading of hides quality, skin and wool. In Ethiopia, though difficult to point out period of the introduction and detail background of the disease, nowadays it is found to be one of the diseases with high economic significance in decreasing the productivity of the animals [34]. Prevalence rates ranging from 4.6-16.3% were reported from different parts of the country [35-37].

**Post Slaughter Defects**

**Poor Pattern:** This is the shape of a skin formed by unaccepted pattern of ripping before flaying. A bad pattern obviously affects the utilization of the leather produced and reduces the marketability of the finished product. The correct method of ripping ensures a uniform pattern, with bellies of equal width, well opened shanks and dewlap, a round butt and adequate tails.

**Putrefaction:** Bacterial and enzymatic breakdown, rotting hide and skin. Hide and skins should be preserved within short period of time, after removed from the carcass to avoid bacterial growth and decomposition of the skin that downgrade the quality of hide and skin (figure 3). It is a commonly seen post slaughtering problem due to improper preservation, exposure of the hide or skin to rain during transportation. Hair slip is the first sign of putrefaction, if hair slip is not checked putrefaction starts from both the grain and flash side leading to decomposition of the grain layer and the flesh side and in advanced cases complete disintegration of the corium may occur [9].

**Poor Bleeding / Veininess:** If the carcass is not well bled-out at the time of slaughtering, blood remains in the vessel and capillaries of the hides and skins. As a result bacteria then develop more rapidly and the veins may show up clearly (in an unsightly way) on the grain surface of the leather [38]. Veiny leather is the result of blood vessels of in the skin where the blood is not completely drained poor through proper bleeding. This is an unwanted effect which shows very clearly in suede leather (figure 4). Veininess is a well-known defect in goat skins and very prominent in glazed kid leather [39].

**Flay Cuts/Hole:** This damage is caused by the careless use of the knife or by the use of unsuitable knives. Flay cuts constitute the most serious mechanical defects on hides and skins (figure 5). Lack of proper tools like
the rounded flaying knives, lack of flaying skills and carelessness lead to loss of quality or outright rejection of raw hides and skins. According CSA [40] survey, knife cut (79.62%) and siding/corduroying/ (37.18%) were the leading defects of the hide in sampled area. In some Ethiopian tannery, 27.8% of skin were reported to have fly cut [22]. In Ethiopia hand flaying is the dominant method of skining in rural and urban slaughtering facilities which exaggerates knife damages, however the immerging modern export abattoirs started to use machine flaying, which is the promising technique that can minimizes the knife contact [12].

Crack: If dried hides are allowed to be flint dry before folding the fiber get ruptured and there will be cracks due to grain rupture (figure 6). In frame drying improper lacing and too much tension will cause distorted shape and rupturing of fibers in thinner portions leading to leather with lower breaking strength and looser structure [9].

ETHIOPIAN HIDE AND SKIN

Fig. 4: Veiny defect low grade wet blue goat skin in Gelan tannery. Source [12]

Fig. 5: Flay hole and corduroying (arrow) on cattle wet blue hide at Colba tannery. Source [12]

CONCLUSINS

ETHIOPIAN HIDE AND SKIN

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Ethiopian hide and skin have a good reputation in the international leather market for their unique natural substance of fitness, cleanness, compactness of texture, thickness, flexibility and strength. However, the leather industry are still constrained by the poor quality of raw materials, due to high prevalence of skin diseases, cultural livestock farming system, common backyard slaughtering technique (which exposed the raw material to a number of defects), lack of an efficient market structure and competition from local/rural tanning industries. Therefore the leather sector which was the 2nd largest export earning of the country dramatically dropped to 5th in the last few years, this is the reflections of the poor pre slaughter, peri and post slaughtering management of the raw material at producers and subsequent actors. Based on these facts responsible stake holders especially the recently named Federal Ministry of livestock and Fishery of Ethiopia should take a serious measure to resolve the constraints.

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