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Dynamics and Driving Forces of Hides and Skins Production and Its Quality Maintenance: The Case in Ethiopia: A Systematic Review of Literature

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ABSTRACT

Hides and skins represent a significant economic sub-sector within Ethiopia's agrarian economy, contributing to export earnings and livelihoods. However, the sector is characterized by a paradox of substantial raw material potential coupled with persistent challenges in quality and value realization. This paper synthesizes existing literature to critically review the dynamics and multifactorial driving forces influencing the production and quality maintenance of hides and skins in Ethiopia. It examines the upstream production constraints, including animal husbandry practices, seasonal variations, disease prevalence (e.g., ectoparasites), and pre-slaughter handling. The review further analyzes the post-slaughter factors, such as flaying techniques, preservation methods, storage, and transportation logistics, which critically determine final product quality and marketability.

The driving forces are explored across institutional, economic, and technical dimensions, encompassing the role of market systems, pricing mechanisms, extension services, and regulatory frameworks. The synthesis reveals that the degradation of hide and skin quality is a systemic issue, stemming from a complex interplay of technical gaps, economic disincentives along the supply chain, and weak coordination among stakeholders. The paper concludes by identifying key knowledge gaps and underscoring the need for integrated interventions that address technical improvements, strengthen market linkages, and enhance policy enforcement to harness the sector's full potential and competitiveness in the global market.

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Introduction

The hides and skins subsector represents a significant, yet historically underexploited, component of Ethiopia's agricultural economy. As the nation possesses Africa's largest livestock population, estimated at over 70 million cattle, 50 million sheep, and 40 million goats, the potential for raw material supply is substantial [1].

However, the economic return from this resource remains sub-optimal, primarily due to pervasive quality deterioration along the value chain. The dynamics of hides and skins production are intrinsically driven by the national livestock population and off-take rates, while the final quality and market value are heavily influenced by a complex array of technical, managerial, and institutional factors that span from farm-level husbandry to post-slaughter processing and preservation [2].

At the production level, pre-slaughter defects such as branding, tick damage, and dermatological diseases severely downgrade raw material quality. These issues are directly linked to traditional animal husbandry practices, limited veterinary care, and poor awareness among producers [3]. Following slaughter, improper flaying, curing, and handling at collection points, tanneries, and during transportation introduce further critical defects like putrefaction, knife cuts, and poor salt penetration. Consequently, a significant portion of Ethiopian hides and skins is relegated to lower grades, fetching diminished prices in international markets and resulting in substantial economic losses [4].

The dynamics driving this production, from animal husbandry practices to slaughtering and post-mortem handling, are multifaceted. Furthermore, the subsequent maintenance of quality is crucial, as defects arising at any stage from pre-slaughter ailments and handling (e.g., branding, parasites, diseases) to poor flaying, curing, and storage can drastically reduce the final value of the raw material [5]. Understanding these interconnected dynamics and quality maintenance issues is paramount for formulating effective strategies to unlock the sector's full economic potential.

Quality maintenance, therefore, relies on systematically mitigating these common defects through integrated improvements in management practices and the standardization of processes across the value chain. Interventions must be multidisciplinary, addressing on-farm animal health, slaughterhouse operations, and the preservation techniques employed by collectors and intermediaries [6]. A comprehensive review and synthesis of existing literature is crucial to consolidate knowledge, identify persistent gaps, and inform cohesive policy and practical interventions.

An Objective of this Review Therefore is to

Systematically analyze and synthesize the existing body of knowledge regarding the hides and skins sector in Ethiopia

The specific objectives are:

- To review the current status and production dynamics of hides and skins in Ethiopia, including the types, sources, and supply chain mechanisms.
- To identify and analyze the primary driving forces that influence the quantity and characteristics of hides and skins production, considering socio-economic and animal management factors.
- To systematically document the major factors affecting the quality maintenance of hides and skins across the entire value chain, from pre-slaughter to storage.
- To synthesize the impact of quality defects on the economic value and export competitiveness of Ethiopia's leather industry.
- To recommend potential intervention areas and future research directions based on the identified gaps in the existing literature.

Methodology

Research Design

This study employed a systematic literature review design, incorporating elements of a critical interpretive synthesis. This approach is chosen to not only summarize existing findings but also to analyze, critique, and synthesize patterns, gaps, and contradictions in the literature concerning Ethiopia's hides and skins sector.

Literature Search Strategy

A multi-pronged search strategy was used to ensure comprehensive coverage. Electronic Databases: Scopus, Web of Science, Google Scholar, PubMed, CAB Abstracts, AGORA and university repositories (e.g., AAU) were used.

Dynamics and Driving Forces

Livestock Population: The Foundation of Supply

Ethiopia possesses one of the largest livestock populations in Africa, which serves as the primary driver for a consistent supply of raw hides and skins. This vast resource base, comprising millions of cattle, sheep, and goats, provides the essential raw material for the sector [7]. The sheer number of animals indicates a significant inherent potential for production. However, the dynamics here are not solely about numbers. The traditional, extensive management systems, coupled with low off take rates, mean that the volume of hides and skins supplied to the market is often less than what the total population would suggest [8]. Furthermore, the quality of the raw material (hide or skin) is intrinsically linked to animal husbandry practices, health, and breeding [9,10]. These factors are often not optimized for skin quality, as the primary focus in production systems remains on meat, milk, or fiber yield [11]. This misalignment leads to a high prevalence of defects, such as parasitic lesions, branding marks, and scratches acquired during the animal's life, which substantially degrade the technical and aesthetic properties of the final leather product [12].

Market Demand: The Pull Factor

High demand from both domestic and international leather industries is a powerful driver of production efforts and economic activity within the sector. The global demand for high-quality leather goods, such as footwear, garments, and accessories, creates a significant "pull" for Ethiopian raw and semi-processed materials [13]. This demand incentivizes collection, grading, and initial processing activities along the supply chain. Domestically, the government's push for industrialization has led to a growing leather products manufacturing sector, which competes with international buyers for quality raw materials [7]. This dual demand structure creates a dynamic where prices and quality requirements are increasingly shaped by global market forces, pushing actors to respond to the often-divergent specifications of both local tanneries and export markets. This phenomenon, where producers must navigate and comply with multiple sets of standards, is a key feature of integration into global value chains [14]. The pressure from export markets, in particular, often necessitates significant upgrading in processes and product quality to meet stringent international norms [15]. Simultaneously, the persistence of local demand creates a complex economic landscape where firms must develop the capability to operate in distinct, and sometimes competing, regulatory and commercial environments [16].

Economic Policy: Shaping Industrial Direction

Government economic policies are a decisive force in shaping the structure and direction of the hides and skins industry. A central policy has been the imposition of higher taxes on the export of raw hides and skins and semi-processed leather (e.g., wet-blue or crust) to encourage domestic value addition through the production of finished leather and manufactured goods as cited in [7]. This policy aims to catalyze industrial development, create jobs, and capture more value within the country. While successful in spurring the growth of tanneries and some footwear factories, this policy has also created market distortions. For instance, it can lead to a glut of semi-processed leather in the domestic market if local manufacturers lack the capacity to absorb it, potentially suppressing prices and profitability [13]. The policy, therefore, directly influences whether the sector remains a supplier of raw materials or evolves into a mature leather products industry.

Price Incentives: The Critical Barrier to Quality

Perhaps the most significant barrier to quality maintenance is the lack of a transparent and effective quality-based pricing system. Currently, the price received for high-quality hides and skins is not adequately differentiated from that of low-quality, defective ones [17]. This market failure creates a perverse incentive structure. As noted, producers, collectors, and traders have little economic motivation to invest the extra time, effort, and cost required for proper flaying, preservation, and handling [18]. If a poorly flayed, salt-deficient hide fetches a price similar to a meticulously handled one, rational economic actors will not engage in quality-conscious practices. This dynamic perpetuates a cycle of low quality, which in turn reduces the competitiveness and export value of Ethiopian leather in the global market, where premium prices are paid for premium quality.

The Pivotal Role of Infrastructure & Technology

The hides and skins sector is a significant contributor to Ethiopia's economy, being a major source of foreign exchange earnings and livelihood for millions. However, the sector's potential remains constrained by a complex interplay of factors, among which infrastructure and technology are paramount. The availability, or more accurately the thereof, of modern facilities and technologies at various stages of the value chain is a primary determinant of both the quantity and, more critically, the quality of the final output.

The Upstream Bottleneck: Traditional Slaughtering Practices

The journey of a hide or skin begins at the point of slaughter, and here, the infrastructural deficit is most acute. The vast majority of animals in Ethiopia are slaughtered in municipal or informal

abattoirs that lack basic hygiene facilities, refrigeration, and trained personnel. Note that "traditional slaughtering practices, which account for over 85% of total slaughters, are characterized by the use of unsanitary facilities and unskilled butchers, leading to extensive flayning cuts, dirt contamination, and poor initial preservation" (p 45) [19]. These mechanical damages knife cuts, scores, and gouges severely degrade the quality of the hides and skins, relegating it to a lower grade and diminishing its value by up to 50% before it even leaves the slaughterhouse.

The driving force for this dynamic is primarily economic and institutional. As highlighted by Gebreeyesus and Sonobe, investment in modern, public or private slaughterhouses is capital-intensive and has not kept pace with the growing livestock population [20]. The lack of enforcement of standard operating procedures and quality-based pricing at this initial stage provides no incentive for butchers to adopt careful flaying techniques. Consequently, the potential for high-quality output is compromised at the very first link in the value chain.

The Critical Preservation Stage: Inadequate Technology and Its Consequences

Once flayed, hides and skins enter the most critical phase for quality maintenance: preservation, the goal of which is to arrest decomposition by inhibiting bacterial growth [21]. In Ethiopia, the dominant method is sun-drying, a low-technology approach that is highly dependent on climatic conditions and prone to significant quality defects [22]. The lack of modern preservation facilities, such as solar dryers or salt-curing plants, means that producers rely on spreading raw hides on the ground, often on dirt, sand, or concrete [23]. This practice leads to a range of defects, including putrefaction, hair slip, and flay cuts, which ultimately degrade the final leather product [24]. Assefa and Tassew empirically demonstrated that "improper drying methods, including direct exposure to ground dirt and intense sunlight, are the leading causes of putrefaction, hair slip, and bacterial damage, which collectively account for over 70% of pre-tanning quality rejections" [25]. The driving force here is the high cost and inconsistent supply of common salt, which makes salt-curing the global standard for quality preservation prohibitively expensive for most small-scale collectors and traders.

This technological gap creates a negative feedback loop. The poor quality of raw, sun-dried hides and skins makes them unsuitable for the production of high-value finished leather, forcing tanneries to focus on semi-processed crust leather for export, which fetches a lower price. This limits the profitability and reinvestment capacity of tanneries, thereby perpetuating the cycle of underinvestment in upstream infrastructure and technology [26].

The Mid-Stream Challenge: Collection, Transportation and Storage

The infrastructure deficit within the livestock value chain is acutely evident in its logistical systems. The collection network for hides and skins is highly fragmented, relying on multiple intermediaries who transport these raw commodities from dispersed rural areas to central markets and tanneries. This system is critically hampered by the lack of specialized, refrigerated transportation, a deficiency that means poorly preserved hides and skins are subjected to further damage and deterioration during transit, directly impacting their quality and value [27]. Furthermore, the storage infrastructure at primary collection points is often inadequate, consisting of basic warehouses without controlled temperature or humidity [28]. This lack of controlled atmospheric storage exacerbates the pre-existing preservation issues, leading to significant material degradation before the hides even reach processing facilities.

Gebreeyesus and Sonobe argue that "the absence of a cold chain and controlled atmosphere storage from the point of slaughter to the tannery gate is the single greatest infrastructural barrier to achieving international quality standards" (p 18) [20]. This logistical failure exacerbates the quality losses initiated by poor slaughtering and preservation, further eroding the economic value of the commodity.

Driving Forces for Change

The dynamics of the Ethiopian hides and skins sector are heavily influenced by a critical deficit in infrastructure and technology. The lack of modern slaughterhouses leads to initial damage, the absence of efficient preservation technology causes rapid deterioration, and inadequate logistics infrastructure compounds these losses.

The Primary Driving Forces Behind this Status Quo are

Financial Constraints: High capital costs for establishing modern abattoirs, curing facilities, and cold chains.

Institutional Weaknesses: Lack of effective regulation, quality enforcement, and extension services at the upstream level.

Market Structure: A fragmented supply chain with a predominance of small-scale actors who lack the capital and incentive to invest in quality-improving technologies.

Addressing these challenges requires a coordinated, value-chain-wide approach. Interventions must focus on promoting public-private partnerships for building critical infrastructure, facilitating access to affordable preservation technologies like solar dryers, and strengthening the institutional framework to enforce quality-based pricing from the slaughterhouse onward. Only through such integrated efforts can Ethiopia leverage its immense livestock resources to produce high-quality hides and skins that can compete effectively in the global market.

Quality Maintenance of Hides and Skins

Quality deterioration of hides and skins occurs at all stages of the value chain and can be categorized into three main areas: defects originating from the live animal, those arising during the slaughter and flaying process, and those acquired during subsequent post-mortem handling, preservation, and transportation [29]. Pre-slaughter factors, such as parasitic damage, branding marks, and mechanical injuries, compromise the underlying skin structure before processing even begins [30]. The slaughter and flaying stage introduce defects like deep knife cuts, score marks, and poor flaying techniques, which directly reduce the usable area of the leather [31]. Finally, inadequate post-slaughter practices, including improper salting, delayed curing, and unhygienic storage conditions, lead to bacterial decay, hair slip, and putrefaction, which are primary causes of significant economic loss [32,33].

Pre-Slaughter Factors (Animal Husbandry)

Defects at this stage are primarily caused by poor animal husbandry practices.

Diseases & Parasites: Cutaneous diseases such as mange, ringworm, and lumpy skin disease cause inflammatory responses that lead to permanent lesions, scarring, and structural damage to the dermis [34,35]. Similarly, infestations by external parasites including ticks, keds, and lice not only cause direct physical damage through biting and feeding but also incite allergic reactions

and pruritus, leading to scratching, ulcerations, and the creation of holes in the hide [36,37]. The presence of such defects has been shown to severely degrade the intrinsic quality of thehides and skins [38]. This degradation directly diminishes the hide's commercial value and renders it less suitable for high-quality leather production [39,40].

Poor Nutrition: is a significant contributor. Inadequate or unbalanced feed deprives the animal of essential proteins, vitamins, and minerals necessary for robust dermal development. This results in hides that are thin, less elastic, and mechanically weak, often described as "papery leather" [41,42]. Such compromised hides have a reduced density of collagen and elastin fibers, making them highly susceptible to tearing, grain damage, and other defects during the rigors of the tanning and finishing processes [43].

Branding & Injuries: Pre-slaughter factors rooted in animal husbandry are a primary source of defects in hides and skins, with poor management practices directly causing significant damage and economic loss. Branding, particularly the use of hot iron brands, inflicts a severe and permanent wound that destroys the grain pattern and devalues the leather [44,45]. Furthermore, various injuries sustained throughout the animal's life contribute to defects. These include horn rakes from intra-herd aggression, scratches from thorny vegetation or poorly maintained barbed wire fences, and lesions caused by rough handling during routine husbandry, transportation, or within housing facilities [46,47]. Such injuries compromise the integument's integrity, which initiates a complex and imperfect wound healing process. Unlike the embryonic or fetal wound healing that can result in scarless regeneration, repair in postnatal skin often leads to the formation of scars and permanent physical damage [48]. This scar tissue, characterized by a disorganized collagen matrix and the absence of appendages like hair follicles and sebaceous glands, is functionally and cosmetically inferior to native skin, rendering it irreparable in the finished product [49].

Housing Conditions: Pre-slaughter factors in animal husbandry are a primary determinant of the quality of hides and skins, with defects often stemming from suboptimal management practices. Housing conditions represent a critical area, as poorly maintained pens with sharp protrusions, rough surfaces, or abrasive walls can cause scratches, gouges, and other mechanical injuries that severely degrade the hide's value [50]. Furthermore, dirty floors contaminated with feces, urine, and mud create an environment conducive to bacterial growth, leading to defects such as dung stains, hair slip, and epidermal erosion, which compromise the structural integrity and aesthetic quality of the leather [51]. Ultimately, the cumulative damage from such environmental hazards directly translates to significant economic losses for the leather industry [52].

Hides and Skins Quality Maintenance Practices

Maintaining the quality of hides and skins begins with proactive animal husbandry. Implementing regular veterinary care, along with strategic deworming and vaccination programs, is fundamental to preventing diseases and parasitic infestations that can cause defects like scars, tick bites, and branding marks, thereby preserving the integrity of the raw material [53,54]. Furthermore, ensuring animals receive adequate and balanced nutrition is critical for promoting healthy skin development. Deficiencies in essential nutrients such as proteins, vitamins (particularly A and E), and minerals (like zinc and copper) can lead to poor collagen and elastin formation, resulting in thin, weak hides that are more susceptible to damage and of lower commercial value [17,55]. Therefore, a holistic approach combining preventive health and proper nutrition is essential for optimizing hide and skin quality from the source.

To maintain the quality of hides and skins, proactive measures that prevent damage from the earliest stages are critical. The practice of animal identification, while necessary for traceability, is a major cause of defects. To mitigate this, producers should use alternative, less damaging identification methods, with research indicating that methods such as electronic tagging significantly reduce blemish rates compared to traditional hot-iron branding [56]. When branding must be used, applying it in less valuable areas, such as the animal's rump or less dense hair regions, can help preserve the more valuable central hide sections [56]. Furthermore, a primary cause of superficial damage arises from environmental hazards, making it essential to maintain safe housing and fencing. Inadequate facilities with sharp protrusions, rough surfaces, and poorly designed feeding troughs are directly linked to scratches, bites, and other injuries that severely downgrade hide quality [57]. Therefore, investing in well-designed, smooth, and hazard-free infrastructure is a fundamental practice for preserving the integrity and value of the raw material.

Effective quality maintenance of hides and skins begins with proper animal handling, as gentle handling and avoiding overcrowding during transport are critical to prevent bruising and stress-induced defects. These physical injuries and physiological stress responses directly compromise the quality of the raw material, leading to significant economic losses for the leather industry. The resulting wounds caused by factors such as aggressive prodding or fighting in cramped conditions, become sites for microbial invasion and structural weakness in the finished leather [58]. Furthermore, stress-induced defects are not only physical; pre-slaughter stress depletes muscle glycogen, which can raise the pH of the hide post-mortem, creating an environment conducive to bacterial growth and hair slip [59]. Therefore, implementing welfare-focused transport protocols is a fundamental pre-slaughter practice for preserving the intrinsic quality of hides and skins and ensuring they meet the high standards required for premium leather production.

Peri-Slaughter Factors (Slaughtering Process)

These defects arise from improper techniques during the actual slaughtering and flaying process.

Inadequate Facilities & Unskilled Labor: Peri-slaughter factors, which are defects arising from improper techniques during the actual slaughtering and flaying process, are a significant cause of hide and leather quality degradation. A primary contributor to these defects is inadequate facilities and unskilled labor. The use of improper tools, such as dull knives and axes, by untrained workers frequently results in a high incidence of flay cuts, holes, and gouge marks, which subsequently reduces the usable area and value of the hide [60,61]. This problem is particularly prevalent in small-scale and informal slaughtering operations where standardized training and modern equipment are often lacking [62].

Poor Bleeding: Peri-slaughter factors, which are defects arising from improper techniques during the actual slaughtering and flaying process, significantly impact meat quality. A primary example is poor bleeding, where an incomplete exsanguination process leaves residual blood in the carcass. This not only creates visually unappealing dark spots (ecchymosis) on the meat surface but also provides a rich medium that accelerates

microbial proliferation and spoilage [63,64]. The residual blood serum, high in moisture and nutrients such as glucose and amino acids, provides an ideal medium that facilitates rapid bacterial growth [65,66]. This proliferation of spoilage and pathogenic microorganisms accelerates putrefaction, leading to off-odors, discoloration, and a substantial reduction in the shelf-life of the meat product [67]. Furthermore, this compromised microbial status directly impacts the safety of the product by increasing the risk of foodborne pathogens [68].

Unhygienic Practices: Unhygienic practices during the slaughtering process have a profoundly detrimental effect on the quality of hides and skins. A primary cause of quality degradation is slaughtering animals directly on the ground, which leads to immediate contamination of the hides and skins with dirt, manure, and other environmental contaminants [69]. Furthermore, the practice of dragging carcasses across unclean surfaces exacerbates this issue, introducing additional pollutants and physical damage such as scratches. This contamination is critically problematic as it introduces proteolytic enzymes and bacteria that accelerate the degradation of the collagen structure, leading to putrefaction and a significant reduction in the quality and market value of the final leather [70]. Specifically, contamination with gut contents, which contain highly destructive enzymes, rapidly initiates hides and skins damage even before preservation can begin, making the material unsuitable for producing high-grade leather [71].

Hides and Skins Quality Maintenance Practices

The maintenance of raw material quality in hides and skins begins at the slaughtering stage, where the implementation of proper, sharp flaying knives is critical. The use of dull knives leads to scoring and deep cuts, which drastically reduces the quality and value of the leather produced [72]. Furthermore, the adoption of appropriate equipment is essential for minimizing damage. The use of mechanical hoists, for instance, standardizes the flaying process and reduces the physical strain on workers that often leads to accidental cuts and holes [73]. Finally, the humane and effective use of stunning devices prior to slaughter is not only an animal welfare imperative but also a key quality control measure, as it prevents the animal from struggling, which can cause "splash" marks and other defects that degrade the hide [74].

A foundational practice in maintaining the quality of hides and skins begins at the very first stage of the slaughtering process. It is critical to ensure complete and proper bleeding of the animal immediately after stunning. Inadequate bleeding leads to blood spoilage, which causes a condition known as "blood burn," resulting in permanent discoloration, hair slippage, and a weakened fiber structure that degrades the final leather [75,76]. This initial step is paramount because efficient exsanguination removes a primary substrate for microbial growth, thereby reducing the initial bacterial load on the hide and preserving its intrinsic quality for the subsequent tanning processes [77]. As noted by Muhamed et al., the integrity of the collagen network is best preserved when post-mortem changes are managed correctly, starting with rapid and thorough bleeding [78].

Maintaining the quality of hides and skins begins at the slaughtering stage. It is essential to conduct slaughter in clean, hygienic facilities to minimize bacterial contamination from the environment, which can lead to defects like hair slip, staining, and degradation of the collagen structure [79]. Furthermore, it is crucial to avoid dragging hides and skins on the ground, as this practice introduces dirt, fecal matter, and pathogens that can cause mechanical damage and deep bacterial penetration, severely compromising the final leather quality [80].

Integrating quality maintenance practices at the slaughterhouse level begins with comprehensive training. As a foundational practice, it is essential to train slaughterhouse personnel and butchers on correct, humane slaughtering and flaying techniques.

The justification for this is strongly supported by academic research. Firstly, humane handling and proper stunning directly influence the quality of the raw material. Studies have shown that pre-slaughter stress and inhumane handling cause physiological changes in animals, such as glycogen depletion, which can lead to meat quality defects like Dark, Firm, and Dry (DFD) meat in ruminants and Pale, Soft, and Exudative (PSE) meat in pigs [81]. These same stress-induced metabolic changes and physical injuries from poor handling, such as bruising, directly degrade the quality of the hides and skins by causing defects like blood stains, flesh marks, and brand marks, which reduce their commercial value [82].

Furthermore, the technique of flaying (skinning) is a critical control point. Incorrect flaying techniques, such as using excessive knife strokes, making deep cuts, or leaving excess flesh and fat on the skin, create defects that are carried forward through the entire leather manufacturing process. As emphasized by Tadel et al., the proficiency of the butchers is paramount; inadequate skills lead to slicing, score marks, and hole defects, which are major causes of hides and skin downgrading and economic loss in the leather industry [83]. Therefore, targeted training programs that integrate animal welfare principles with precise technical skills are not just an ethical imperative but a crucial economic investment for ensuring the initial quality of hides and skins [84]. Research demonstrates that pre-slaughter stressors and poor handling directly correlate with defects such as branding, scratches, and hides and skin damage, which significantly devalue the raw material and reduce its marketability [85]. Consequently, investing in comprehensive stockperson training that emphasizes low-stress animal handling techniques is a strategic intervention to mitigate these financial losses at the primary production level [86]. Such programs serve the dual purpose of advancing animal welfare outcomes while directly enhancing the quality and economic value of the resulting leather [87].

Post-Slaughter Factors (Preservation, Storage & Transport)

Defects after slaughter are primarily due to delayed or improper preservation methods.

Delayed Preservation: Post-slaughter defects in hides and skins are predominantly attributable to delayed or improper preservation methods. As highly perishable biological materials, hides and skins must be preserved immediately to prevent bacterial and enzymatic degradation. Research emphasizes that a critical window exists, with preservation required within a few hours of flaying, as delays beyond this period lead to a rapid proliferation of bacteria [88,89]. This bacterial activity, particularly from halophilic (salt-loving) and proteolytic (protein-digesting) microbes, directly causes the common and economically significant defect known as "hair slip," where the hair or wool becomes loose and easily pulled from the skin follicle [90,91]. The failure to initiate curing processes, such as salting or drying, within this short timeframe often cited as within six hours in tropical climates irreversibly compromises the collagen structure and leads to substantial quality depreciation and financial loss [92].

Improper Preservation: Post-slaughter factors, particularly those involving preservation, storage, and transport, are critical determinants of final meat quality, with many defects arising from delayed or improper preservation methods. Improper Preservation is a significant issue; for instance, inadequate or unhygienic salting practices, such as the re-use of salt, can introduce spoilage microorganisms and fail to achieve the necessary antimicrobial environment [93]. Similarly, improper drying techniques, such as excessive heat during sun-drying, can cause "case hardening." This defect occurs when the outer surface of the meat dries and hardens too quickly, trapping moisture within and creating favorable conditions for microbial growth and spoilage, thereby compromising the entire preservation process [93,94].

Poor Storage & Transport: Post-slaughter factors, particularly those related to preservation, storage, and transport, are critical determinants of final hide and skin quality. Defects occurring after slaughter are frequently attributable to delayed or improper preservation methods, which fail to curb microbial and enzymatic activity [95]. Furthermore, poor storage and transport conditions are a primary cause of spoilage; inadequate storage environments characterized by high humidity, poor ventilation, and pest infestation, combined with exposure to heat and moisture during transit; create a conducive environment for mold growth, insect damage, and putrefaction [96].

Hides and Skins Quality Maintenance Practices

A critical factor in preserving the quality of raw hides and skins between flaying and tannery processing is the implementation of immediate and proper curing methods. The primary objective of curing is to lower the water content to a level that inhibits bacterial growth, thereby preventing putrefaction and hair slip [97]. For this, adequate wet-salting using high-purity sodium chloride remains the most common and effective method, as it draws out moisture and creates a hypertonic environment that desiccates microbial cells [98]. The efficacy of this process is highly dependent on the application of sufficient salt quantity, uniform distribution, and optimal contact time to ensure thorough penetration. In regions or for specific end-uses where salt is less available or where salt-free preservation is desired, appropriate frame drying in controlled conditions is a viable alternative. This method requires careful management of temperature, humidity, and airflow to achieve uniform drying without case-hardening, where the outer surface hardens and seals in moisture, leading to internal degradation [99]. Ultimately, the consistent application of these scientifically-grounded curing practices is fundamental to minimizing defects and preserving the intrinsic collagen structure, which directly translates to higher-quality leather and enhanced economic value [100-102].

The fundamental principle of preserving the quality of raw hides and skins begins with proper storage. Best practices dictate that hides and skins should be stored in cool, well-ventilated, and pest-proof facilities to mitigate bacterial degradation and insect damage [103]. Furthermore, placing these raw materials on raised wooden pallets is critical, as this practice prevents moisture absorption from the floor, facilitates air circulation on all sides, and reduces the risk of heat buildup and subsequent spoilage [104,105]. This strategic combination of environmental control, such as regulated brine curing and chilled storage to inhibit microbial growth, and physical separation of raw materials is a foundational measure within the leather supply chain to minimize pre-tanning defects [106-108]. This integrated approach is crucial for preserving the intrinsic quality of the hide or skin, thereby directly mitigating economic losses associated with defects like hair slip, putrefaction, and staining that originate in the pre-tanning stages [109,110].

Maintaining the quality of hides and skins throughout the supply chain is critical for preserving their economic value and ensuring their suitability for high-grade leather production. A fundamental practice is the use of appropriate packaging, such as baling or rolling, which protects the hides/skins from physical damage and deformation during handling and transit [111]. Concurrently, stringent control of the environmental conditions during transportation and storage is essential. As noted by uncontrolled temperature and humidity create a conducive environment for microbial growth, leading to irreversible damage like hair slip and putrefaction [112]. Therefore, integrating robust packaging with controlled atmospheric conditions is a primary defense mechanism against quality degradation and contamination [113].

skins#:~:text=Hides%20and%20skins%20may%20be,in%20a%20relatively%20short%20time.

Based on the principle that the optimal packaging method is dictated by the preservation type, hides and skins for international shipment are categorized primarily as wet-salted, dry-salted, or dried. Each method presents distinct risks that packaging must mitigate, primarily concerning moisture management and container integrity.

Wet-Salted hides/skins, which are heavily impregnated with corrosive brine, demand the most robust packaging protocols. The primary requirement is a heavy-duty, one-piece plastic or woven polythene liner (a minimum thickness of 0.2mm is often specified) to contain the aggressive brine leakage, which can damage container floors and co-mingled cargo [114]. Furthermore, an absorbent material such as fine-grade sawdust must be spread on the container floor to soak up excess liquid, and the use of pallets is critical to elevate the hides/skins, preventing them from sitting in pooled effluent. The entire cargo should be enclosed in a "bathtub" style liner, where the sides are folded up to create a complete barrier and prevent spills from escaping the designated containment area [115].

Wet salted hides; Source: CINS (2017) https://www.cinsnet.com/wp-content/uploads/2017/12/CINS-Guidelines-Hides-and-Skins-Guidelines-Final-30-October-2017.pdf

In contrast, Dry-Salted and Dried hides/skins generally require less intensive lining. However, due to the hygroscopic nature of salt and the hides/skins themselves, a floor covering of cardboard or a layer of sawdust is recommended to manage potential condensation. This "container rain" can occur during transit due to climatic variations, which may cause minor re-wetting and leakage [116]. These hides/skins are typically compressed and shipped in bales for efficiency.

Finally, Wet Blue hides/skins, which have been chrome-tanned, are chemically stable and represent a lower risk. As they are typically shipped shrink-wrapped on pallets, no special container preparation is necessary beyond a visual inspection to ensure the industrial wrapping is intact, as their stability prevents the exudation of corrosive liquids [114].

Wet blue hides; Source: CINS (2017)

General Best Practices

Container Inspection

Before loading any hides or skins, it is imperative to conduct a thorough visual and physical inspection of the container. The objective is to identify and mitigate any sharp protrusions, exposed nails, splinters, or residual debris that could puncture or tear the protective liners or the hides/skins themselves. As noted in a comprehensive review of leather processing, physical damage from poor handling and unsuitable containers is a major cause of defects that degrade leather quality [102]. Any identified rough surfaces must be covered using appropriate materials such as cardboard, foam, or durable fabric to create a smooth, inert internal environment. This practice directly prevents mechanical damage like scratches and gouges, which can become sites for bacterial proliferation if the hide's grain layer is compromised.

The rationale for this rigorous inspection extends beyond immediate physical damage. A punctured liner can lead to fluid leakage, creating a potential environmental hazard and promoting the growth of salt-loving bacteria, such as *Halobacterium salinarium*, which causes the severe defect known as "red heat" [117]. Furthermore, research has shown that the initial microbial load on hides is a key predictor of both hides/skins deterioration and potential cross-contamination with pathogens like *E. coli* and *Salmonella* during transport [118]. A clean, intact container is the first line of defense in minimizing this microbial risk.

Integrated Best Practices

Building upon the critical step of container inspection, the following integrated practices are essential for optimal preservation:

Rapid Cooling and Salting

Immediately after flaying, hides/skins must be cooled to retard bacterial growth. Wet-salting (curing) with high-purity sodium chloride is the most common preservation method. The salt draws out moisture and creates a hyperosmotic environment, inhibiting microbial activity. The effectiveness of this process is highly dependent on uniform application and adequate pressure during stacking [119].

Proper Folding and Stacking

The correct physical handling of cured hides is essential to protect their economic value. The standard industry practice is to fold hides with the flesh-to-flesh and hair-side out configuration. This method directly shields the delicate and valuable grain layer (the corium side) from mechanical abrasion and environmental exposure during handling [120]. Furthermore, when stacked for storage or transport, hides/skins must be placed on pallets or spaced battens. This arrangement is critical to allow for drainage of residual moisture and promote air circulation around each hides/skins. Inadequate stacking can lead to the formation of "heat spots" and localized putrefaction, as trapped moisture and heat create ideal conditions for bacterial re-growth, compromising the entire curing process [121].

Temperature and Humidity Control

Maintaining a stable environment is crucial to sustain the preservative effect of salting. During transportation, a cool, dry environment must be preserved. While refrigerated transport is ideal, even ambient-temperature movement requires strict avoidance of direct sunlight and high-humidity conditions. Exposure to heat and moisture can rapidly reverse the curing process by dissolving the salt concentration at the hides/skins surface, lowering the water activity (a_w) and re-initiating bacterial and fungal proliferation [122]. As noted in research on collagen stability, fluctuations in temperature and humidity directly accelerate hydrolytic degradation, leading to permanent hides/skins damage [123].

Traceability and Rotation

Effective inventory management is a key non-physical safeguard against spoilage. Implementing a First-In-First-Out (FIFO) inventory system ensures that hides/skins are processed before the effective shelf life of the cure expires. This minimizes the risk of spoilage from prolonged storage, where even well-cured hides/skins can deteriorate. FIFO, supported by clear lot tracking, is a cornerstone of quality assurance in perishable goods logistics and is directly applicable to raw hides/skins preservation [124]. Prolonged storage, even under good conditions, increases the risk of salt migration, moisture absorption, and subsequent hide/skin quality degradation, making systematic rotation a critical control point.

Protection Against Physical Damage: A fundamental practice to prevent physical damage, particularly from mechanical handling, is the strategic use of protective layers. As highlighted in the guideline, "Use cardboard or particle board on the floor, both below and above the liner, to prevent the liner from being damaged by forklifts or shifting pallets." This method addresses a common point of failure in the supply chain.

The reasoning behind this practice is twofold. First, placing a rigid layer (cardboard or particle board) on the floor beneath the palletized hide/skins creates a barrier that distributes the pressure from a forklift's tynes during pickup, preventing them from piercing the bottom liner or hide. Second, placing a similar board on top of the stacked hides/skins before they are wrapped or covered protects the uppermost hides from compression, abrasion, and impact from other shifting pallets or mishandling during transit and storage. This is crucial because, as research indicates, "physical damage due to improper handling and storage accounts for a significant percentage of pre-tanning defects [102]. These

defects, including cuts, tears, and deep abrasions, can severely downgrade the leather.

Furthermore, the use of such protective boards is part of a larger system of unitization. Proper palletization and unit load stability are essential to prevent load shifting, which can cause compression damage and render entire batches unsaleable. The principles of secure packaging and load distribution in perishable goods logistics directly apply to hides and skins [125]. By integrating a simple, low-cost material like particle board, the entire unit's integrity is significantly enhanced, protecting the high-value commodity within.

Other Foundational Best Practices
While physical protection is critical, it must be integrated with other key practices:

Effective Curing and Temporary Preservation: The primary goal of curing is to remove moisture to inhibit bacterial growth. Salt curing remains the most common method. However, inadequate or uneven curing leads to bacterial damage like "slipping" (hair loss) and red heat. Best practices involve using clean, fine-grade salt and ensuring thorough coverage and pressing to achieve moisture content below 40% [126].

Controlled Storage Conditions: Cured hides must be stored in a cool, dry, and well-ventilated environment. High humidity can rehydrate the hide/skin, restarting bacterial decay, while excessive heat can cause hide/skin proteins to denature. Ventilation is key to dissipating heat and moisture released from the hides [127].

Proper Packaging and Stacking: Hides/skins are typically palletized and wrapped. It is essential to avoid over-stacking pallets, as the immense pressure can cause "heat spots" and thermal degradation in the lower layers. Pallets should be stacked on a raised platform to avoid direct contact with the floor, preventing moisture absorption and contamination.

Hygiene and Sanitation: The storage facility must be kept clean to prevent contamination from dirt, blood, and other biological matter. Pallets and equipment should be regularly cleaned and sanitized to break the cycle of bacterial cross-contamination [102].

Ventilation and Stowage
Inadequate storage and transportation can lead to irreversible damage, such as bacterial degradation, hair slip, and putrefaction, which directly impacts the economic value and quality of the final leather product [128]. The core principles governing these logistics are centered on temperature control, ventilation, and proper stowage.

Ventilation and Stowage
Effective ventilation is paramount, as hides/skins are hygroscopic and biologically active materials. Even after curing, hides/skins retain moisture and continue to respire, generating heat and odours. If this heat and moisture are not dissipated, they create a microenvironment conducive to the rapid growth of bacteria and fungi, leading to hide/skins spoilage [129]. Therefore, ensuring adequate air circulation around the hides during both storage and transportation is a non-negotiable practice.

Regarding stowage, particularly in containerized shipping, the standard best practice is to stow hides on deck, if possible. This placement allows for better natural ventilation around the container and reduces the risk of contaminating other cargo with odours. Containers should never be exposed to direct heat or sunlight for prolonged periods, as elevated temperatures accelerate bacterial growth and can cause premature drying or case-hardening a condition where the outer surface hardens while the inner flesh remains wet and putrefies [130]. As noted in industry guidelines, "containers should be stowed on deck, if possible, and not exposed to direct heat or sunlight. Ensure adequate air circulation" [131].

Curing and Initial Preservation
Before storage or long-distance transport,hides/skins must be properly cured to reduce their water activity and inhibit microbial growth. The most common method is salting (sodium chloride application). Research has shown that the efficacy of salting depends on the thoroughness of application and the quality of the salt used [132]. Hides/skins must be uniformly salted, flesh-side up, in a cool, well-ventilated area and then stacked to allow brine to drain away. Insufficient or uneven curing at this stage will compromise the hides/skins stability during subsequent transportation, regardless of other precautions taken.

Temperature and Humidity Control
Maintaining a low and stable temperature is crucial to suppress microbial metabolism. While refrigeration is ideal, it is often not feasible for large volumes during transportation. Therefore, the focus shifts to passive cooling through ventilation and shade. The relative humidity (RH) should also be controlled; high RH promotes microbial growth, while very low RH can cause excessive moisture loss and brittleness. A study on hide/skin preservation found that a stable, cool environment with moderate RH is optimal for maintaining hide/skin integrity during storage [133].

Packaging and Handling
Cured hides/skins are typically bundled into bales for transportation. These bales must not be over-tightened, as this restricts internal air circulation, creating pockets for heat and microbial growth. Furthermore, bales should be handled carefully to avoid physical damage such as tears or scratches, which can become focal points for degradation [130]. The use of pallets for floor storage is recommended to elevate the bales and promote air movement on all sides.

Documentation and Labeling
General Best Practices for Hide and Skin Storage and Transportation
The preservation of hide and skin quality from the point of flaying until they reach the tannery is critical for the leather industry's economic and operational efficiency. Inadequate practices during these stages can lead to irreversible defects, substantial financial losses, and potential regulatory non-compliance. A systematic approach encompassing preservation, storage, and transportation is therefore essential.

Preservation and Curing
The primary goal immediately after flaying is to lower the water activity in the hides/skin to inhibit bacterial growth. Two common methods are salting and drying. Wet-salting (curing with granular salt) is highly effective, as it rapidly dehydrates the skin and creates a hypertonic environment. As noted in a study on hide preservation, "the application of salt reduces the moisture content and prevents the growth of bacteria and other microorganisms" [134]. Inadequate or uneven salt application is a well-documented leading cause of hair slip and putrefaction during hide/skin preservation, as the insufficient sodium chloride concentration fails to inhibit microbial growth effectively [135,136]. Alternatively, air-drying is used as a preservation method in certain climates but requires careful control of temperature and humidity to prevent

case-hardening. This phenomenon occurs when the outer surface of the hide/skin dries too quickly and forms a hardened layer that seals moisture within, creating an anaerobic environment conducive to bacterial spoilage [137,138].

Storage Best Practices

Proper storage acts as a buffer between preservation and transportation, stabilizing the hides/skins until they are shipped.

Temperature and Humidity Control: Storage facilities must be cool, well-ventilated, and dry to ensure the preservation of cured hides/skins. High temperatures are a primary driver of deterioration, as they significantly accelerate bacterial activity and enzymatic degradation [139]. Concurrently, high humidity poses a critical risk to salt-cured products, as it can dissolve the protective salt cake that draws moisture out of the hide. This dissolution allows for the re-hydration of the collagen matrix, creating a favorable environment for microbial growth and effectively restarting the spoilage process [140]. Therefore, maintaining a stable, cool, and dry environment is paramount to sustaining the cured state by suppressing both microbial and physicochemical spoilage mechanisms, a principle widely supported in preservation science [141].

Stacking and Handling: Based on best practices in the leather industry, proper stacking and handling are critical for preserving hide quality. Hides/skins should be stacked on pallets to avoid direct contact with the floor, which allows for essential air circulation and mitigates the risk of moisture absorption and microbial degradation [102]. Furthermore, they should not be compressed excessively, as this can trap heat and create anaerobic pockets where bacteria can thrive [142]. This compression-induced heating, combined with a lack of oxygen, provides an ideal environment for the proliferation of proteolytic bacteria, leading to irreversible damage such as hair slip and hide decomposition [127].

Pest Control: Facilities must be secured against pests, such as insects and rodents, as they are not merely a nuisance but a significant source of physical damage. This damage can manifest as the gnawing of electrical wires and structural components, contamination of products, and general deterioration of building integrity [143]. The foundational principle of Integrated Pest Management (IPM) emphasizes that exclusion the physical sealing of a facility to prevent pest entry is the most critical and sustainable first line of defense, as it addresses the problem at its source rather than relying solely on reactive pesticide applications [144]. Consequently, proactive pest exclusion is a non-negotiable aspect of asset protection and risk management, directly preserving the physical and economic value of a facility [145].

Transportation Best Practices

The principles of storage largely extend to transportation, with an added emphasis on physical protection and environmental sealing.

Packaging: Proper packaging is critical for preserving the quality of hides during transport and storage. Industry best practices and research indicate that hides are typically bundled and packed in secure, breathable containers, such as woven polypropylene bags, which allow for sufficient air exchange to prevent moisture accumulation [146]. The use of non-breathable, airtight plastic liners is strongly discouraged for standard shipments, as they trap moisture and promote "sweating," which creates a favorable environment for bacterial growth and subsequent hide damage [147,148]. This trapped moisture significantly increases the risk of bacterial proliferation, leading to discoloration, degradation of collagen fibers, and a substantial loss in hide quality and value [149]. The exception to this rule is when hides are shipped in refrigerated containers, where the controlled low temperature mitigates the risk of moisture-related spoilage, making sealed liners a viable option for protection against external contaminants [146].

Loading and Securing: Containers must be clean, dry, and free of contaminants to prevent cargo degradation and comply with international phytosanitary measures, a foundational principle in intermodal logistics [150]. Furthermore, loads should be securely fastened to prevent shifting during transit, which can cause physical damage like scratches or tears. The dynamics of cargo movement during transport, including acceleration, braking, and cornering forces, create significant risks that must be mitigated through proper blocking and bracing techniques [151]. Failure to adequately secure cargo is a primary cause of damage and loss, underscoring that effective restraint is not merely a procedural step but a critical engineering requirement for supply chain integrity [152].

Environmental Control: For long-distance shipments, particularly in maritime logistics, the use of refrigerated containers, or "reefers," is established as a best practice for preserving perishable goods. This technology is critical for maintaining a constant, low-temperature environment throughout the cold chain, which directly mitigates the risk of spoilage and quality degradation, even when faced with extended or unpredictable transit times [153]. The efficacy of this approach is contingent on proper operational protocols, as the benefits of the technology can be negated by poor temperature management during loading and unloading phases [154].

Documentation and Labeling

This is a critical, yet often underestimated, component of the supply chain. Proper documentation ensures regulatory compliance, traceability, and smooth customs clearance.

As a foundational practice, every consignment must be clearly labeled and include all necessary documentation. This packet should include a detailed shipping manifest, a commercial invoice, and any required veterinary or sanitary certificates to prove the hides are from disease-free animals. For species listed under the Convention on International Trade in Endangered Species (CITES), proper CITES permits and tags are legally mandatory. Given the potential for exposure to moisture during transit, it is a critical best practice to seal all these documents in a waterproof bag and securely attach it to the consignment [155]. This simple step prevents the irreversible damage or loss of critical information, which can lead to costly delays, seizures, or legal penalties at port entries. As emphasizes, "incomplete or damaged documentation is a primary non-tariff barrier in the international trade of raw hides" [155].

Conclusion and Recommendation

Conclusion

The review of literature conclusively affirms that Ethiopia's hides and skins sector is a strategic economic asset fueled by the nation's immense livestock population, which serves as the primary driving force for production volume. The sector holds significant potential for foreign exchange earnings and supports the burgeoning domestic leather industry [156].

However, the sector's dynamics are severely constrained by a pervasive, multi-stage quality crisis. The literature consistently highlights that the principal challenge to the quality maintenance of hides and skins is the high prevalence of defects, with sources

indicating that up to 65% of damages occur pre-slaughter due to poor animal husbandry practices. This includes: Pre-Slaughter Defects: Ectoparasites (especially ticks causing "cockle"), branding, poor housing, and injuries from transportation; Peri- and Post-Slaughter Defects: Poor flaying techniques (flay cuts), improper handling, and inadequate preservation methods (lack of proper salting/drying, poor storage) [157].

Furthermore, the value chain suffers from market inefficiencies, such as the absence of a consistently enforced, quality-based grading and pricing system, which removes the incentive for primary producers and collectors to invest in quality improvement. This results in the bulk of raw materials being relegated to lower-quality, lower-value markets, preventing the country from fully capitalizing on its natural resource base [158].

Recommendations

To unlock the full economic potential of the hides and skins sector in Ethiopia, a coordinated, multi-stakeholder strategy focusing on four interdependent pillars is recommended:

Strengthen Animal Husbandry and Health (Pre-Slaughter)

- **Integrated Disease and Parasite Control:** Implement robust, coordinated national programs for regular dipping, spraying, and vaccination, particularly targeting ectoparasites like ticks, which are major causes of skin defects.
- **Modern Identification Methods:** Issue a directive to phase out hot-iron branding and mandate the use of humane, non-damaging alternatives like ear tags or microchips for livestock identification.
- **Extension and Training:** Design and deliver comprehensive training packages to livestock holders on balanced nutrition, safe handling, appropriate housing (to prevent scratch injuries), and the economic value of high-quality hides and skins.

Upgrade Slaughter and Preservation Infrastructure

- **Modernize Facilities:** Invest in the construction and upgrade of municipal abattoirs and slaughter slabs with proper tools and infrastructure for efficient, humane slaughter and clean flaying.
- **Professional Training:** Institute mandatory and regular training for butchers and flayers on proper flaying techniques to minimize cuts and scores, and ensure immediate and correct post-mortem handling.
- **Standardize Preservation:** Promote and subsidize the correct use of salt preservation techniques (salting) in collection centers and along the value chain, coupled with training on proper drying and storage to prevent putrefaction.

Introduce and Enforce Quality-Based Marketing

- **Implement Grading System:** Immediately revive and strictly enforce the existing Ethiopian Hides and Skins Grading Standards at the first point of transaction (from the producer/collector).
- **Incentivize Quality:** Establish a clear and significant price differential based on the official quality grades to reward producers who supply defect-free raw materials. This is the single most effective way to drive quality change throughout the value chain.
- **Market Information:** Improve transparency by providing stakeholders (producers, collectors, and traders) with real-time, quality-based market information and pricing.

Policy, Coordination and Research

- **Establish a Steering Committee:** Form a high-level, multi-stakeholder body (government, tanneries, producers' associations, and researchers) to oversee the implementation of the quality improvement strategy and coordinate efforts across the different ministries (Agriculture, Trade, and Industry).
- **Invest in R&D:** Fund research into Ethiopian-specific challenges, such as the efficacy of indigenous parasite control methods and the development of cost-effective preservation techniques suitable for remote areas.

Declarations

Author's Contribution

Not applicable

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