Selcuk Journal of Agriculture and Food Sciences

https://dergipark.org.tr/tr/pub/selcukjafsci

Research Article

(2026) 40 (2), 384-403 DOI:10.15316/selcukjafsci.1947178 e-ISSN: 2458-8377 Selcuk J Agr Food Sci

By-Product Management in Sustainable Livestock Farming: Transformation of Leather Waste Through Art "Waste Vest Examples"

Yasemin Koparan[1*]

[1] Selcuk University, Faculty of Architecture and Design, Department of Handicrafts, Konya, Türkiye

HIGHLIGHTS

- Recover hides obtained from Turkey's livestock potential.
- Leather waste comes back to life through art.
- The economy and ensuring economic sustainability.
- using the zero-waste method as part of sustainability

Abstract

Leather, a strategic by-product of the livestock production process, is one of the most fundamental raw material sources for the agricultural-based industry. However, today the leather sector faces problems such as quality losses stemming from animal husbandry conditions and environmental pollution caused by tanning processes. This study examines the transformation of waste generated during the production phase in the leather industry into high value-added wearable art (vest) products within the framework of circular economy principles. The study first addresses the large and small livestock population in Turkey, housing conditions and their effects on the quality of leather raw materials after slaughter. The study highlights the damage caused by chemical methods applied in leather tanning to water resources and ecosystems and discusses the management of leather waste generated from the production line. Industrial waste leathers are considered as the primary design material in this study. This study, a mixed-methods action research approach was employed, combining qualitative and quantitative techniques. Within the scope of the study, 9 vests were designed from waste leather pieces using zero-waste techniques, transforming them into wearable products with high aesthetic and functional value. Colored waste nappa leather ranging from 1.5 mm to 2 mm in thickness was used in the production of the vests. To assess the design process and wearability of the produced vests, the "Design Evaluation Scale" was administered to 7 field experts and the evaluations were made based on weighting. Additionally, internal consistency of the vests and evaluation criteria was analyzed using Cronbach's Alpha coefficient, resulting in a score of 80.9%, which indicates a good overall success rate. The findings reveal that such upcycling models aim to minimize the volume of agricultural and industrial waste and create artistic and economic added value from discarded materials.

Keywords: Sustainable; Leather waste; Upcycling; Value added; Design; Handicrafts

Citation: Koparan, Y. (2026). By-Product Management in Sustainable Livestock Farming: Transformation of Leather Waste Through Art "Waste Vest Examples". *Selcuk Journal of Agriculture and Food Sciences*, 40 (2), 384-403. https://doi.org/10.15316/selcukjafsci.1947178

Corresponding Author E-mail: yaseran@hotmail.com

Received date: 08/05/2026

Accepted date: 23/06/2026

1. Introduction

Livestock farming, one of the fundamental building blocks of agricultural production and rural development, holds a strategic place and strong potential in the Turkish economy. The sector plays a critical role in the balanced nutrition of society by meeting the needs of the rapidly growing population for biologically valuable nutrients such as meat, milk, and eggs (Ergün and Bayram 2021; İşler and Ören, 2021; Akın, 2025). However, livestock farming not only ensures food security; it also creates multifaceted economic value by supplying raw materials and byproducts to agriculture-based industries (Kılıç, 2025; Duran and Çayın, 2026). This integration generates significant added value for the national economy by creating extensive employment opportunities in many different sectors, such as feed production, meat and milk processing, veterinary medicine, livestock equipment, and, in particular, the leather and textile industries (Demir, 2012). To give examples of these economic contributions; hides and raw skins, which are basic by-products of animal production, form the main input of the leather industry and feed labor-intensive production sectors such as shoes, bags, and clothing. Similarly, animal fibers such as wool, mohair, and silk are utilized in the textile industry in a wide range of applications such as yarn, ready-made clothing, and carpet weaving.

Leather, a primary byproduct of livestock farming, has been one of humanity’s most basic needs throughout history and has become one of the agricultural outputs with the highest economic added value today. According to reports from the United Nations Food and Agriculture Organization of the (FAO, 2022), industrially processing raw hides obtained from cattle and sheep is essentially a massive agricultural waste management practice and has transformed into a multi-billion-dollar global industry. This transformation represents one of the most fundamental examples of the integration of agriculture with industry. From a macroeconomic perspective, Turkey, with its livestock population, possesses a very strong raw material potential for this global leather industry.

Cattle and small ruminant breeding, one of the key components of livestock production, is of strategic importance to the agricultural sector (Akinci and Yılmaz, 2026). According to the latest data from the Turkish Statistical Institute (TUIK, 2025), the number of cattle in Turkey increased by 4.3% compared to the previous year, reaching 17,709,000 head, while the number of small ruminants increased by 5.4% compared to the previous year, reaching 57,874,000 head. In the bovines category, the number of cattle increased by 4.3% compared to the previous year, reaching 17,544,000 head, and the number of buffaloes increased by 1.7% compared to the previous year, reaching 164,785 head. In the small ruminant category, the number of sheep increased by 5.9% compared to the previous year, reaching 46,689,000 head, and the number of goats increased by 3.4% compared to the previous year, reaching 11,186,000 head (Table 1). According to Anonymous (2026). The main reasons for this increase in animal populations are government subsidies, increased roughage quantities, and imports. This livestock potential means that hundreds of thousands of tonsof raw hides are transferred to industry every year. However, the quality of the final leather product is not a matter of chance; it directly depends on the quality of the live material and the ecological and physiological conditions the animal is exposed to throughout its life cycle.

Table 1. Animal numbers and change rates, 2024-2025 (TUIK,2025)

	2024	2025	(Head) Change (%)
Bovines	16 986 256	17 708 985	4,3
Cattle	16 824 208	17 544 200	4,3
Buffalo	162 051	164 785	1,7
Small Ruminants	54 902 668	57 874 318	5,4
Sheep	44 080 584	46 688 813	5,9
Goat	10 822 084	11 185 505	3,4

Negative housing conditions during the animal raising process, inadequate nutrition, external parasite (tick, scabies, etc.) infestations, and substandard slaughtering practices cause irreversible damage to the topographical structure of raw hides, resulting in significant economic losses (Ebrahiem et al., 2015). Within the framework of general zootechnical principles, the technological and industrial quality of an animal hide is determined by multiple factors such as the animal's species, breed, age, sex, climatic conditions to which the animal is exposed, and its feeding regime (Karaoğlu et al., 2023). Specifically, when the age factor is examined; as the animal ages, changes in the cross-links in the collagen fiber structure cause loosening of the skin tissue and thickening of the grain layer, most valuable layer of the skin, thus reducing quality. In terms of the sex factor, although female animal hides have a tighter fiber structure and a thinner grain layer compared to male hides, the physiological stress caused by repeated pregnancies and lactation processes negatively affects the elasticity and quality of the hide over time (Kalkan, 1963; Çevikkol et al., 2023; Karaoğlu et al., 2023). Environmental and climatic factors also directly shape the histological structure of the hide. The hides of animals adapted to cold and harsh climatic conditions have a more resistant tissue structure and a smoother surface compared to those raised in temperate climates. In terms of feeding and breeding models, the hides of animals raised in pasture-based systems where they roam freely and are fed fresh green forage exhibit significantly superior structural characteristics compared to those of animals in confined barn systems (Ebrahiem et al., 2015; Güler, 2025). On the other hand, one-sided genetic selections carried out in industrial livestock farms, focusing solely on high meat, milk, or wool yields, can lead to the physiological development of the hide being neglected. In this context, the attention paid to animal welfare, balanced rations, and preventive veterinary care under controlled breeding conditions is the most fundamental requirement for obtaining high-quality raw hide (Çevikkol et al., 2023). To ensure this quality, shelters should be insulated against wire mesh and sharp surfaces that could mechanically damage the skin, regular treatment programs against external parasites (ticks, scabies) should not be neglected, and rations should be enriched with trace minerals such as copper to strengthen skin elasticity. Furthermore, instead of one-way genetic advancement, multi-faceted breeding (selection) programs targeting areas not specified in the structural characteristics of the skin should be preferred (Leach and Wilson 1995).

The leather industry has a unique characteristic unlike any other sector, directly due to the distinctive texture of the leather, its raw material, and its ability to maintain this texture until it reaches the consumer. However, the leather industry produces a large amount of waste in various forms, such as solid, liquid, and gas, during the tanning and product manufacturing processes (Özgünay et al., 2007; Kanagaraj et al., 2015). Chemicals containing a wide variety of organic and inorganic compounds are used to transform and process raw hides into commercially valuable leather (Ortega et al., 2005; Paschoal et al., 2009). Toxic gases such as ammonia and hydrogen sulfide are also released (Thanikaivelan et al., 2005). Such toxic gas emissions primarily occur in chrome tanning facilities, which is the most widely utilized method in the modern leather industry to meet the demands of the footwear and apparel sectors. From a historical perspective, hides and skins were predominantly processed using ecological and vegetable tanning methods until the Industrial Revolution; however, driven by the need for increased speed and production capacity, these gave way to chemical methods starting in the late 19th century (Navarro et al., 2020). Specifically, sodium sulfide and ammonium salts, which are introduced into the system to accelerate preliminary processes such as unhairing and deliming (bating), constitute the primary source of the aforementioned toxic gases in contemporary industrial leather manufacturing (Krishnamoorthy et al., 2012). Chromium tanning is the most widely used method in the world due to its ease of production and the smoothness of the leather surface. Chromium-tanned leathers are more durable, resistant, firm, and have higher density than vegetable-tanned leathers; however, chromium contains chemicals and is quite harmful to the environment, making its use a controversial topic (Krishnamoorthy et al., 2013; Zuriaga-Agustí et al., 2015; Navarro et al., 2020;). Furthermore, the chromium tanning method consumes large amounts of water and leads to significant pollutants (wastewater). Wastewater constitutes 90% of the pollution generated in a tannery (Mella et al., 2015; Dixit et al., 2015). Processing 1 kg of raw leather requires 30 to 50 liters of water. Research shows that the global leather industry produces 548 billion liters of wastewater annually (Sathish et al., 2016). Leather produced using chrome tanning systems is difficult to biodegrade, posing a serious threat to the environment. Poor management of these wastes leads to serious pollution problems and disrupts the ecological balance (Greenwell et al., 2016; Arellano-Sánchez et al., 2022).

Leather is the most widely traded material in the world and generates the most waste. Leather waste is classified into various categories (Figure 1). Waste generated by tanneries is an unavoidable byproduct and poses a serious threat to the environment (Zuriaga-Agustí et al., 2015). Waste remaining from the manufacturing stage, such as cuts of finished leather, shoes, clothing, furniture, etc., is generally used as low-value-added filler material or incinerated, increasing the carbon footprint of the sector (Bayramoğlu, 2019). Leather waste generated from the sale of leather products, including returned products, waste remaining from damaged products, and leather products discarded by consumers when they are no longer needed, is generally of low quality and poor condition since these materials are second-hand products (Pringle et al., 2016). In addressing these problems, it is crucial for local policy and economic development leaders to support value-added products, and circular economy approaches that view waste not as trash but as a new raw material in order to strengthen rural economies and ensure environmental sustainability (Özkan, 2024; Er and Erol 2025).

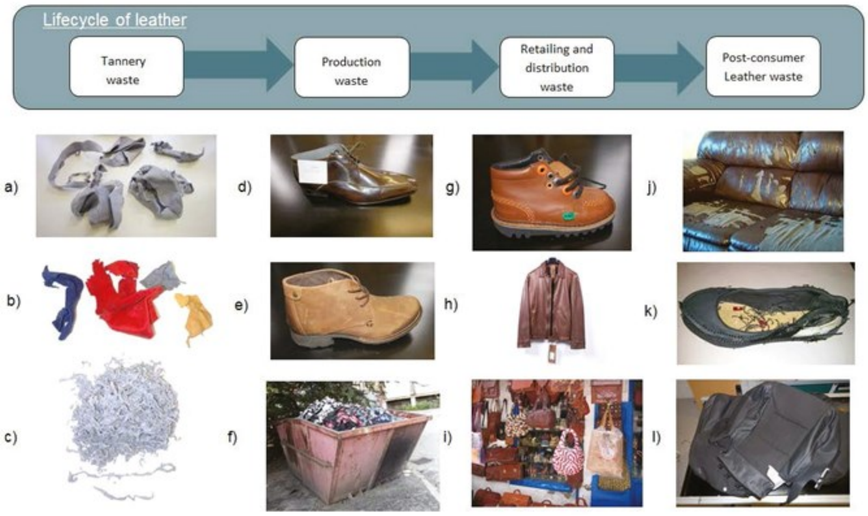

Figure 1. Leather Waste Lifecycle (Pringle et al., 2016)

To ensure sustainability, it is necessary to protect the environment, and to protect the environment, sustainable development must be achieved. Waste is of great importance in achieving sustainable development. Waste material should not only be seen as a pollutant to the environment, but also as a very good source of recyclable material and raw material (Valentin et al., 2014). According to Anonymous (2026a), waste is defined as "any substance or material that is discarded, left in the environment or required to be disposed of by its producer or by a natural or legal person who actually possesses it." Waste management is directly related to the economic, social, and political conditions of countries. When waste is managed properly, the need for natural resources and the damage to the environment decrease (Alemu et al., 2021). In this context, the concept of innovation emerges, referring to the introduction of a new idea that improves quality of life, is benefit-oriented, marketable, accepted by the consumer, and brings more profit to the producer than ever before (Ocakoğlu, 2018). Innovative and beneficial products must not harm the environment, be recyclable, and not consume natural resources. In this case, the concept of green products, which meet these qualities, emerges (Yıldız and Kütahyalı, 2021). Green products can be defined as products that create less pollution, are made of recyclable materials, save water and energy to reduce the disposal times of waste, packaging, and toxic substances, and are produced by making greater use of renewable resources in production (Chen and Hung, 2016). A green product is one that undergoes recycling processes for decomposition or reuse after its useful life is complete. In this context, handicrafts have the potential to offer an aesthetic and economic solution to waste management by combining traditional techniques with modern sustainability approaches.

This study aims to recover hides obtained from Turkey's livestock potential, but which becomes waste in the industrial process, in order to ensure environmental and economic sustainability. It brings together the disciplines of agriculture and livestock farming (raw material production), industry (leather processing and waste), and art and design. Reprocessing waste leather in artistic forms will not only offer a solution to agricultural and industrial waste management but will also enable the creation of cultural products with high economic value from zero-cost waste. It is also considered an important study in terms of presenting a unique interdisciplinary model.

2. Materials and Methods

The study was designed in accordance with the principles of qualitative and quantitative research design. In the study, the action research approach, which is an applied problem-solving and improvement process within the scope of the descriptive method, was adopted. Action research is a scientific approach that enables practitioners to understand problems in their own fields through a systematic data collection and reflective inquiry process, and to bring about change through cyclical steps by developing action plans (Gürgür, 2016). This method combines theoretical knowledge with practical application, offers on-site solutions to existing problems, and facilitates the use of qualitative data collection techniques with its process-oriented structure (Yıldırım and Şimşek, 2013). In the study, new vest designs were created from leather pieces obtained from textile industry production waste, and the designs were evaluated. In the development of the designs, the general forms, dimensions, types, sizes, and colors of the leather pieces of the vests were taken into consideration, and the surface- forming patterns were examined. The study aims to contribute to both the environmental and economic aspects of sustainability with vest designs made from waste leather pieces.

2.1. The process of producing vests from waste leather

Within the scope of the study, nine upcycled vests in various styles were produced using waste leather pieces that would otherwise be discarded during the leather industry's saddlery and garment leather production stages. This not only ensured sustainability by utilizing waste leather but also created fashionable and practical new vest designs.

The zero-waste approach, which emerged as part of sustainability efforts, was employed in the study. The aim of zero-waste design is to eliminate or minimize waste generation during the design and production phases (McQuillan, 2011; Niinimäki, 2013). The goal is to produce products in full accordance with the "zero waste, zero scrap" principle. McQuillan conducted one of the most significant and pioneering studies in the field of zero-waste design. McQuillan (2011) developed four approaches for zero-waste fashion design: mosaic tiling, jigsaw, embedded jigsaw, and multi-fabric methods. In light of these explanations, the mosaic and jigsaw from zero-waste design techniques were used in the study to create products from leather pieces. Colored waste nappa leathers between 1.5 mm and 2 mm in thickness were used for vests. Nappa leather is generally obtained by tanning the hides of small and large livestock, such as lamb, sheep, goat, calf, and cattle, using chromium salts. These leathers have a smooth or grainy surface, are thin, soft, flexible, and durable, and come in various colors (Özdemir and Kayabaşı, 2007). They are commonly used in the footwear, bag, and textile industries.

2.2. Statistics analysis

In this study, the "Design Evaluation Scale" was used to both manage the creative process and measure success in the production of the vests (Table 2). The absence of a standard measurement tool in the literature that directly and comprehensively evaluates handicraft design processes necessitated the development of this scale. To test the content validity and construct validity of the scale, the opinions of five field experts from the Department of Handicrafts and Fashion Design at Selçuk University Faculty of Architecture and Design were sought. Based on the feedback received from the experts through face-to-face interviews, the necessary revisions were made, and the scale was finalized into its 8-item form. The "Weighted Decision Matrix" method was used to evaluate the design products with objective criteria. This method constitutes a multi-criteria decision-making approach employed to ground the decision process on an objective and analytical foundation when selecting from a variety of alternatives (Mazak and Kratzwald, 2014)

Weighted Score = Criterion Score * (Criterion Weight / 100)

Total Score = Σ (Weighted Scores)

For evaluation, the scale was presented to 3 field experts from the Department of Handicrafts, 2 from the Department of Fashion Design, Faculty of Architecture and Design, Selçuk University, and 2 from the Department of Textile, Clothing, Footwear and Leather, Technical Vocational School, Konya Technical University. Each product was examined individually and evaluated independently. The design evaluation scale was rated as 1= Very Inadequate, 2= Inadequate, 3= Moderate, 4= Adequate, 5= Very Adequate. The data obtained were evaluated qualitatively based on weighted scoring of the answers and the determination of a "weight" (percentage) according to the importance of each criterion. Formula: (Total Score Obtained / Maximum Possible Score) x 100

Table 2. Industrial Waste Vest Design Evaluation Scale

	Evaluation Criteria	Weight (%)	1 (Very Inadequate)	2 (Inadequate)	3 (Moderate)	4 (Adequate)	5 (Very Adequate)
1	Compliance with the Zero Waste Principle	20%					
2	Aesthetics and Originality	15%					
3	Functionality	10%					
4	Usability / Ergonomics	10%					
5	Quality of Craftsmanship	10%					
6	Manufacturability	10%					
7	Sustainability	15%					
8	Innovation	10%					

Furthermore, in this study, Cronbach's alpha statistic was utilized to evaluate the internal consistency among the seven experts, taking into account the design evaluation scores assigned by the experts to all vest designs. The reliability analysis was performed using SPSS 18.0 software for Windows (Statistics PASW, 2009).

3. Results

The integration of sustainable livestock farming and the leather industry requires not only the efficient use of raw materials but also the reintegration of post-production waste into the circular economy. The waste generated during the production stages of saddlery and clothing leather varies considerably in volume and shape. In this context, the study involved a leather surface treatment with minimal waste, taking into account the structure, material, and technical properties of the waste leather pieces.

Figure 2. Production of Vest from Waste Leather

The vest design in Figure 2 was created using waste leather pieces, a byproduct of the leather industry, in accordance with sustainable design principles. It was recreated using a mosaic tiling technique to transform it into a functional outerwear garment with zero waste. In the design, adhering to the principle of seamless combination of geometric forms as defined by McQuillan (2011), the body integrity of the vest was created by bringing together square-shaped leather modules. This mosaic structure, composed of yellow, blue, white, and navy colors, offers an aesthetic rhythm while maximizing material efficiency and minimizing waste during the production phase. The edges of the mosaic surfaces applied to the front and back of the vest were perforated with leather punching tools. Using a crochet stitch technique, the leather pieces were joined with floss thread. This joining technique supports the advanced upcycling model of sustainability by making the segmented structure a characteristic element of the design rather than hiding it. A visual balance was established between the main leather piece used in the shoulder and collar sections of the product and the multicolored mosaic pieces at the bottom. Furthermore, the embroidery on the upper part of the back section, using traditional cross-stitch techniques, demonstrates that zero-waste method can also be integrated with elements of cultural sustainability.

Vest design 1 was evaluated by experts, and the results are presented in Table 3. Examining this table, it can be seen that the vast majority of scores are concentrated the 5-point range, with the lowest score being 4. No expert assigned a score of 1 (Very Inadequate), 2 (Inadequate), or 3 (Moderate). This narrow range between evaluations (low variance) indicates a very strong consensus and agreement among the experts.

Table 3. Weighted score table for waste leather vest design 1.

Design.1	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average(%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	33	4,95
3	Functionality	10%	35	3,5
4	Usability / Ergonomics	10%	35	3,5
5	Quality of Craftsmanship	10%	35	3,5
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	33	3,3
	Total	100%	(max.280) 276	34,5

Accordingly, the success rate of vest design 1 is 34.5/35*100=98.57.

The vest achieved a very high success rate of 98.57% in the overall evaluation of the experts, thereby more than adequately meeting the sustainable design criteria.

Figure 3. Production of Vest from Waste Leather

The design shown in Figure 3 utilizes waste leather pieces in accordance with the zero-waste principle. The design is a long, tunic-like vest. To completely eliminate waste, the pieces were cut into rectangular and square forms of specific sizes. The use of rectangular shapes visually enhances the length of the vest while also increasing the flexibility of the mosaic system. In addition to the mosaic tiling, a single, large piece of tanned leather is used in the center of the back panel. A stylized plant motif in shades of green, blue, and yellow was embellished on this surface using a stepping needle stitch technique, adding aesthetic and cultural value to the design. All forms and the edges of the central back piece were perforated at equal intervals with a leather punching tool for joining. The hole spacing was calculated precisely to avoid distorting the angles at the corners. Green, mustard yellow, tan, and navy-blue colors were used to create a cohesive visual rhythm. Each piece was joined together using the single-loop braided stitch, which is one of the leather stitching techniques. The transitions were accentuated using cream-colored waxed cord in the joining process, transforming it into a visual manifesto. In the final stage, the collar, sleeves, and hem edges were finished using the same stitching technique, and the product was completed.

The evaluation of Vest Design 2 is presented in Table 4. According to this table, the vast majority of scores are concentrated in the 4 and 5 ranges, with the lowest score being 3. No expert assigned a score of 1 (Very Inadequate) or 2 (Inadequate). This narrow range of scores indicates consensus and agreement among the experts.

Table 4. Weighted score table for waste leather vest design 2.

Design 2	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	30	4,5
3	Functionality	10%	35	3,5
4	Usability / Ergonomics	10%	33	3,3
5	Quality of Craftsmanship	10%	33	3,3
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	33	3,3
	Total	100%	(max.280) 269	33,65

Total percentage = 33.65/35*100 = 96.14 is the success rate of vest design 2.

The vest achieved a high success rate of 96.14% in the overall evaluation of the experts, thus meeting the sustainable design criteria.

The front of the vest The back of the vest The right of the vest The left of the vest

Figure 4. Production of Vest from Waste Leather

Figure 4 shows a vest made using leather scraps combined with crochet work. Unlike previous vertical and horizontal mosaic patterns, this design utilizes a rhombus (diamond) shape. These shapes were perforated at equal intervals along the edges using a leather punching tool to allow for joining. Pieces of waste leather in shades of pink, white, and khaki were combined with crocheted pieces stitched with brown yarn to create a cohesive surface. The use of crochet not only as a joining element but also as a surface module in itself presented flexibility and drape to the otherwise rigid and durable leather material. This hybrid approach combines the zero-waste design philosophy with traditional craft practices, adding an innovative and cultural dimension in terms of sustainability. The waste leather pieces, arranged according to the zero-waste principle, were selected considering color harmony and surface thickness. To join the leather pieces and the crochet work together and to fill the gaps in the design, crochet was used again for joining. In this process, which was the most distinctive stage of the design, two different techniques were applied simultaneously. All exposed outer edges of the vest were finished using the same crochet technique to maintain the integrity of the design and to fix the final form.

The design evaluation for Vest Design 3 is presented in Table 5. According to this table, the majority of scores are concentrated in the 5, 4, and 3 ranges, with the lowest score being 2. No expert assigned a score of 1 (Very Inadequate). This narrow range in the evaluations indicates consensus and agreement among the experts.

Table 5. Weighted score table for waste leather vest design 3.

Design 3	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	33	4,6
2	Aesthetics and Originality	15%	35	4,2
3	Functionality	10%	35	3
4	Usability / Ergonomics	10%	35	3,5
5	Quality of Craftsmanship	10%	35	2,8
6	Manufacturability	10%	33	3,5
7	Sustainability	15%	35	4,4
8	Innovation	10%	35	2,9
	Total	100%	(max.280) 237	28,9

Total percentage = 28.9/35*100 = 82.57 is the success rate of vest design 3.

Vest design 3 achieved a success rate of 82.57% in the overall evaluation of the experts. Although it has a high success rate, it is slightly lower than the other two vest designs. This was interpreted by the experts as being due to the excessive use of crochet. However, it is still observed to meet sustainable design criteria.

Figure 5. Production of Vest from Waste Leather

The design shown in Figure 5 adheres to the principle of zero waste and zero scraps. Instead of cutting leather pieces into straight or sharply angular geometries as observed in previous works, the pieces were cut using patterns that follow each other's curves. This approach ensures the most efficient use of naturally asymmetry leather pieces with almost no waste. The design uses shades of light blue, yellow, beige, and green. Red leather piping was used at the joining points of the pieces and along the entire outer edge of the vest, creating a visual framing. At the center of the back panel of the design, stylized plant motifs were arranged in the form of a circular medallion featuring a lace-like texture created using openwork technique. The edges of all the pieces were perforated with a leather punching tool and joined using single-loop stitch technique, one of the leather stitching techniques, with yellow glittered rayon-blend yarn. The circumference of the circular form, which serves as the focal point of the back body, is formed into a strip by crocheting with a glittered rayon-blend yarn using the openwork technique and then joined to the other curved pieces.

Leather waste vest design number 4 was evaluated by experts, and the results are presented in Table 6. Upon examining the table, it can be seen that the vast majority of scores are concentrated in the 5-point range, with the lowest score being 4. No expert assigned a score of 1 (Very Inadequate), 2 (Inadequate), or 3 (Moderate). This indicates a very strong consensus and agreement among the experts.

Table 6. Weighted score table for waste leather vest design 4.

Design 4	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	35	5,3
3	Functionality	10%	33	3,3
4	Usability / Ergonomics	10%	33	3,3
5	Quality of Craftsmanship	10%	32	3,5
6	Manufacturability	10%	35	3,3
7	Sustainability	15%	35	5,3
8	Innovation	10%	35	3,5
	Total	100%	(max.280) 274	34,5

Accordingly, when calculated as a percentage, the success rate for Vest Design 4 is 34.5/35 × 100 = 98.57.

In the overall evaluation of this design, it achieved a very high success rate of 98.57%. This indicates that it more than adequately meets the sustainable design criteria.

Figure 6. Production of Vest from Waste Leathe

When examining the design in Figure 6, it is evident that the potential of leather waste is fully utilized through the use of standardized pieces. The entire vest was created by combining single-colored square leather waste pieces. Each edge of the black leather, cut into equal pieces, was perforated with a leather punching tool. The main characteristic of the design is that it was stitched on a black surface using marbled waxed yarn in blue, yellow, red, and green tones, creating a strong contrast through the application of the cross-stitching leather joining technique. This stitching technique, using marbled waxed yarn, ensures the structural integrity of the leather while also giving the vest a dynamic structure. Furthermore, the zipper used to close the vest proves that zero-waste designs can be adapted to everyday use in a highly functional way.

The design evaluation of vest design 5 is presented in Table 7. Looking at this table, it can be seen that the vast majority of scores are concentrated in the 4 and 5 ranges, with the lowest score being 3. No expert assigned a score of 1 (Very Inadequate) or 2 (Inadequate). The small difference in scores between the evaluations indicates consensus and agreement among the experts.

Table 7. Weighted score table for waste leather vest design 5.

Design 5	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	29	4,35
3	Functionality	10%	35	3,5
4	Usability / Ergonomics	10%	35	3,5
5	Quality of Craftsmanship	10%	33	3,3
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	32	3,2
	Total	100%	(max.280) 269	33,6

Accordingly, when calculated as a percentage, the success rate for Vest Design 5 is 33.6/35*100=96

The vest more than adequately meets the sustainable design criteria, achieving a 96% success rate in the overall evaluation of the experts.

Figure 7. Production of Vest from Waste Leathe

The design in Figure 7 demonstrates that leather waste can be transformed into artistic value through figurative composition techniques in the upcycling process. Unlike previous geometric and curved designs, this vest design uses irregularly shaped and free-form leather pieces. The focal point of the design, the back, features a stylized horse head figure created by combining leather waste of different colors and textures. In the front, circular and crescent-shaped pieces were positioned to create an asymmetrical balance. The color palette, dominated by earth tones (brown, beige, tan), was enlivened with vibrant colors such as red, green, yellow, and orange, symbolizing the vibrancy of the natural material. The lacing system used at the front closure ensures the vest's integration with the aesthetics of traditional leather craftsmanship. Technically, the design incorporated a joining technique based on free-form placement. Leather joining and embellishment, including cross-stitching, diagonal wrapping, and single-loop braiding, were used in combination. Additionally, open eyelets were attached to pass the laces used in the front closure. In this design, the stitches not only serve a joining function but also act as contours defining the figure's outer lines. The circular modules on the front panels were similarly appliquéd onto the base leather via stitching. Unlike other models, in this process, a compositional outline (such as a horse figure) was created according to the sizes of the pieces. The smallest pieces of leather waste were set aside for the figure's details (eyes, nose, mane line), while the larger pieces were allocated for the body and base sections. Freeform cutting, the most advanced level of the puzzle technique included in McQuillan's (2011) zero-waste strategies, was applied. Each piece was cut millimeter-precisely according to the negative form of the next piece, ensuring there were no gaps between the pieces.

The evaluation results for Vest Design 6 are presented in Table 8. Looking at this table, it can be seen that the majority of scores are concentrated in the 5 range, with the lowest score being 4. No expert assigned a score of 1 (Very Inadequate), 2 (Inadequate), or 3 (Moderate). This narrow range in the evaluations indicates a very strong consensus and agreement among the experts.

Table 8. Weighted score table for waste leather vest design 6.

Design 6	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	30	4,5
3	Functionality	10%	35	3,5
4	Usability / Ergonomics	10%	33	3,3
5	Quality of Craftsmanship	10%	33	3,3
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	33	3,3
	Total	100%	(max.280) 269	33,65

Accordingly, when calculated as a percentage, the success rate for vest design 6 is 33.65/35*100=96.14

The vest achieved a very high success rate of 96.14% in the general evaluation of the experts. Therefore, it more than adequately met the sustainable design criteria.

Figure 8. Production of Vest from Waste Leather

Figure 8 shows a vest design created by combining curved cuts that provide the natural symmetry of the material, in contrast to geometric forms. The main body of the design was formed by arranging leather panels in beige, pink, and light green symmetrically along a vertical axis. The most distinctive visual feature that sets this design apart from others is the crochet embellishment technique used at the shoulder and front section junctions. This technique presented a breathable, lightweight, and elegant texture to a dense and closed material like leather. The 'V' shaped zigzag cuts applied to the hem of the vest add dynamic movement, while transforming the material's natural symmetry into a design advantage. In line with the zero-waste principle, long and narrow leather scraps were reserved for this design. Cutting the pieces vertically both increased the longitudinal efficiency of the material and ensured that the garment created a longer silhouette on the wearer. The edges of each vertically cut piece were perforated at equal intervals using a leather punching tool. In order to preserve the integrity of the design, the crochet embellishment was joined using off-white rayon yarn with the single-loop stitch technique, one of the leather joining techniques.

The leather waste vest design 7 was evaluated and is presented in Table 9. Looking at this table, it can be seen that the vast majority of scores are concentrated in the 5 range, with the lowest score being 4. No expert assigned a score of 1 (Very Inadequate), 2 (Inadequate), or 3 (Moderate). This indicates a consensus among the experts.

Table 9. Weighted score table for waste leather vest design 7.

Design 7	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	30	4,5
3	Functionality	10%	35	3,5
4	Usability / Ergonomics	10%	33	3,3
5	Quality of Craftsmanship	10%	33	3,3
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	33	3,3
	Total	100%	(max.280) 269	33,65

Accordingly, when calculated as a percentage, the success rate of vest design 7 is 33,65/35*100=96,14

The vest achieved a very high success rate of 96,14% in the overall evaluation of the experts, receiving the same percentage as designs 1, 4 and 6. Therefore, it met the sustainable design criteria.

Figure 9. Production of Vest from Waste Leather

The vest design examined in Figure 9 was created using a zero-waste technique on waste leather pieces composed of squares, but with a polygonal geometric form. Using the mosaic technique, one of the most effective methods for reducing waste to zero, all waste leather was cut into equal pieces. However, when placing them, some square pieces were arranged in a rhombus (diamond) shape. The angled placement of the pattern allowed the pieces to interlock without gaps. The juxtaposition of green, blue, gray, and black colors created a three-dimensional optical illusion on the surface. The edges of the pieces were perforated at equal intervals with a leather punching tool to allow for joining. The leather pieces were joined with cross-stitch using light brown waxed yarn, a technique used in leather joining.

Design 8 of the waste leather vest was evaluated by experts, and the results are presented in Table 10. Upon examining the table, it can be observed that the majority of scores are concentrated in the 4 and 5 ranges, with the lowest score being 3. No expert assigned a score of 1 (Very Inadequate) or 2 (Inadequate). This indicates a consensus among the experts.

Table 10. Weighted score table for waste leather vest design 8.

Design 8	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	31	4,65
3	Functionality	10%	33	3,3
4	Usability / Ergonomics	10%	33	3,3
5	Quality of Craftsmanship	10%	26	2,6
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	35	3,5
	Total	100%	(max.280) 263	33,1

When calculated as a percentage, the success rate of vest design 8 is 33.1/35*100=94.57.

The vest achieved a success rate of 94.57% in the overall evaluation of the experts. This shows that it met the sustainable design criteria.

Figure 10. Production of Vest from Waste Leather

In the final design shown in Figure 10, an asymmetrical and versatile zero-waste approach was implemented, utilizing leather industry waste in large-surface pieces. Unlike the small and standardized mosaics of previous designs, this design features larger, differently sized rectangular leather pieces that interlock like a jigsaw puzzle. The use of contrasting colors such as blue, white, brown, and orange in large pieces gives the design a modern and dynamic identity. The edges of the pieces were perforated at equal intervals with a leather punching tool for assembly and joined using single-loop stitching with orange waxed yarn. The use of large pieces minimized energy consumption and labor time. Angular pieces with the largest surface area were selected for this model from among the waste leather pieces. The main goal was to maximize the use of the existing width of the waste material instead of creating extra waste by dividing the leather into small pieces. The pieces were not cut according to a specific standard (e.g., 10x10 squares); instead, the right-angled edges of each piece were matched to fill the space of another piece. This method is a geometric version of the free-form construction found in the zero-waste literature.

The evaluation results for vest design 9 are presented in Table 11. Upon examining the table, it can be seen that the scores are in the 4 and5 ranges. No expert assigned a score of 1 (Very Inadequate), 2 (Inadequate), or 3 (Moderate). This indicates a consensus among the experts in the evaluation.

Table 11. Weighted score table of waste leather vest design 9.

Design 9	Evaluation Criteria	Weight (%)	Assessment of Designs	Weighted Average (%)
1	Compliance with the Zero Waste Principle	20%	35	7
2	Aesthetics and Originality	15%	35	5,25
3	Functionality	10%	33	3,3
4	Usability / Ergonomics	10%	33	3,3
5	Quality of Craftsmanship	10%	32	3,2
6	Manufacturability	10%	35	3,5
7	Sustainability	15%	35	5,25
8	Innovation	10%	35	3,5
	Total	100%	(max.280) 273	34,3

When calculated as a percentage, the success rate of vest design 9 is 34.3/35*100=98.

The vest achieved a 98% success rate in the overall evaluation of the experts. This shows that it met the sustainable design criteria.

In the study, internal consistency for different vests and evaluation criteria was analyzed with Cronbach's Alpha coefficient. The results are presented in Table 12.

Table 12. Consistency Among Experts Based on Vests and Evaluation Criteria

Vests	α	Evaluation Criteria	α
1	1	Compliance with the Zero Waste Principle	0.859
2	0.750	Aesthetics and Originality	1
3	0.789	Functionality	0.892
4	0.396	Usability / Ergonomics	0.842
5	0.920	Quality of Craftsmanship	0.911
6	0.763	Manufacturability	0.735
7	1	Sustainability	1
8	0.711	Innovation	0.387
9	0.647		
Overall Mean (α)= 0.809			

α: Cronbach's Alfa

Consistencies (α) according to vests and evaluation criteria were evaluated from 9 different assessors. Thus, nine assessors and eight evaluation criteria were considered for compliance in the analysis ($P<0.01$).

According to Table 12, the overall average α value is 0.809, indicating a good level of reliability in the evaluations. However, low internal consistency values were observed in some vests (especially vest 4, α = 0.396) and criteria (Innovation, α = 0.387). This may be due to different subjective interpretations of the relevant criteria. In contrast, very high values such as α = 1.00 were obtained in some criteria, which can be explained by low variance or complete agreement among the raters.

The "Design Evaluation Scale" was administered to 7 field experts to assess the design aspects of the vests made from leather waste, and the success rates of the obtained data are presented in Figure 11. As shown in Figure 11, the overall success rates of the 9 different waste leather vest designs evaluated by field experts are at a very high level.

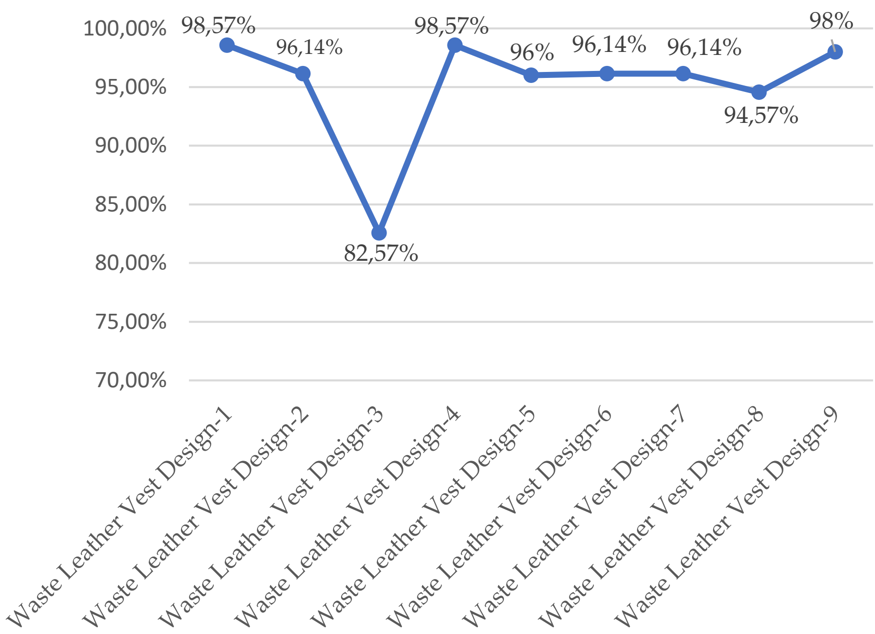

Figure 11. Success Rations of Waste Leather Vest Designs (%)

4. Discussion

The findings of this study demonstrate that leather, as a strategic agricultural byproduct, can be successfully reintegrated into the macroeconomic cycle through sustainable upcycling, rather than being discarded as industrial waste. The exceptionally high expert evaluation scores (ranging between 82.5% and 98.57%) practically validate the zero-waste fashion design frameworks pioneered by McQuillan (2011). While traditional linear patternmaking in the fashion industry inherently generates 15% to 20% material waste, the modular cutting and joining techniques applied in this collection prove that it is possible to achieve near-absolute material efficiency, thereby confirming the sustainable fashion principles advocated by Niinimäki (2013).

The variations in expert scores across the designs provide important insights into material behavior and aesthetics. The relatively lower performance of Design 3 (85.42%), which heavily featured crochet work, suggests that while hybrid material experimentation is highly valued, preserving the visual and structural integrity of the primary material (leather) is crucial for the overall aesthetic coherence of upcycled garments. Conversely, the peak scores achieved by designs utilizing natural material symmetry (Design 7) and free-form figurative composition (Design 6) indicate that highlighting the authentic, biological characteristics of leather increases the perceived value of the handicraft.

From an environmental perspective, utilizing industrial waste leather directly addresses the severe pollution and carbon footprint challenges highlighted by Bayramoğlu (2019) and Zuriaga-Agustí et al. (2015). Instead of subjecting these scraps to low-value filler processes or energy-intensive incineration, transforming them into high-value wearable art offers eco-friendly waste management alternative that strongly supports the circular economy principles emphasized by Özkan (2024) and Er and Erol (2025).

Finally, a consistency analysis of the Design Evaluation Scale, administered to 7 field experts, was conducted, and the result was found to be 80.9%, demonstrating agreement among the experts and confirming the reliability of the evaluation.

While the findings are highly positive, this production model presents certain sector-specific limitations regarding its integration into mass production on an industrial scale. Sorting waste leather, establishing the right balance between thickness and flexibility, and especially the free-form cutting and hand-stitching stages require intensive labor. This can increase production costs and times, leading to the positioning of the products in a niche market. In future research, it is suggested that semi-industrial methods be developed to optimize these modular zero-waste systems with laser cutting technologies, thereby shortening production times. In addition, ergonomic tests and consumer acceptance analyses conducted on different age and gender groups will provide important data for increasing the market share of such sustainable products.

5. Conclusions

This study highlights that by-product management in sustainable livestock farming should not be confined to chemical recycling or raw material processing; instead, it can be extended into the realm of artistic upcycling and high-value product design. By rejecting the fast-fashion paradigm, this research demonstrates how industrial leather waste can be transformed into durable, aesthetically superior cultural products, thereby actively reducing the textile sector's environmental burden, water footprint, and chemical waste load. Crucially, because the repurposing of leather waste through upcycling eliminates the need for a secondary tanning process, further water consumption and environmental pollution are prevented at the source; this, in turn, significantly reduces the cumulative water and carbon footprints of the artistic transformation process in question.

The primary scientific significance of this research lies in its execution of a concrete, interdisciplinary action model that bridges the gaps between livestock agriculture, industrial tannery management, and traditional/modern handicrafts. Unlike existing literature which predominantly focuses on the chemical biodegradation of leather industry waste, this study contributes a novel methodology by showing that zero-cost industrial waste can be utilized directly as a primary design material without requiring additional energy-consuming industrial processes. Furthermore, it addresses a prominent gap in national literature, where interdisciplinary upcycling models for leather waste remain scarce, establishing a conceptual framework for industrial ecology within creative disciplines

While the produced collection pecifically exemplified by the developed "Waste Vest" prototypes demonstrates the immense potential of zero-waste design, certain sector-specific limitations exist regarding scalability. The manual sorting, thickness-balancing, and hand-stitching phases are highly labour-intensive, which currently positions these products within a niche or bespoke market. To overcome these constraints, future research should explore the integration of semi-industrial methods, such as utilizing advanced laser-cutting technologies to optimize modular zero-waste layouts and shorten production cycles. Additionally, conducting comprehensive ergonomic testing and consumer acceptance analyses across diverse demographic groups will be essential to expanding the market share and commercial viability of such sustainable, circular economy products. Ultimately, this research redefines industrial leather waste not as an environmental liability, but as a fertile ground for cultural preservation and ecological innovation

Author Contributions: The article was written by a single author. All contributions, including conceptualization, methodology, software, validation, formal analysis, research, project management, and funding, were made by Y.K. The author has read and approved the published version of the article.

Funding: This research received no external funding.

Acknowledgments: I would like to thank Aslı Duman, Fatma Nur Arslan, Günnur Doğan, Betül Kaya, Esra Karagöz, A. Berinay Çiftçioğlu, Nurhan Kabaklı, Fatma Batalak and Şeymanur Canseven for their support in the production range of vest designs.

Conflicts of Interest: The authors declare no conflict of interest.

References

Alemu, K., Assefa, T., Debebe, A., Solomon, B., & Hailu, Y. (2021). Goods reinforcement from waste leather, fabric, and low-density polyethylene by using plant binder. *Polymer Composites*, 42(6), 2787-2794. https://doi.org/10.1002/pc.26013

Akın, A. C. (2025). *Hayvansal Üretimin Türkiye Ekonomisindeki Yeri ve Önemi*. (Editör: Z. Bulut). Türkiye'de Hayvancılığın Gelişimi: Sorun Alanları, Fırsatlar ve Politika Öngörüleri. 1. Baskı. Türk Akademisi Siyasi Sosyal Stratejik Araştırmalar Vakfı (TASAV).

Akinci, M., & Yılmaz, H. (2026). Devlet Destekli Büyükbaş Hayvan Hayat Sigortası Uygulamalarının Süt Sığırcılığı İşletmeleri Açısından Değerlendirilmesi: Burdur İli Örneği. *Uluslararası Gıda Tarım ve Hayvan Bilimleri Dergisi*, 6(1), 47-68.

Anonymous, (2026). *Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Livestock, Presidential Decree Regarding Livestock Support to be Provided in 2024-2026* https://www.tarimorman.gov.tr/HAYGEM/Haber/388/2024-2026-Yillarinda-Yapilacak Hayvancilik-Desteklemelerine-Iliskin-Cumhurbaskanligi-Karari-Yayinlandi. (Access date:25.05.2026).

Anonymous, (2026a). *Republic of Turkey Ministry of Environment, Urbanization and Climate Change Waste Management Regulation*, https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=20644&MevzuatTur=7&MevzuatTertip=5, (access date: 12.04.2026).

Arellano-Sánchez, M. G., Devouge-Boyer, C., Hubert-Roux, M., Afonso, C., & Mignot, M. (2022). Chromium Determination in Leather And Other Matrices: A Review. *Critical Reviews in Analytical Chemisry*, 52(7), 1537-1556. https://doi.org/10.1080/10408347.2021.1890545

Bayramoğlu, E. E., (2019). *Sürdürülebilir İşletmecilik Anlayışı: Deri Sanayinde Atıkların Katma Değeri Yüksek Ürün Haline Dönüştürülmesi.* Proceedings of the International Congress on Business and Marketing, Maltepe Üniversitesi, İstanbul, 13-14.06.2019.

Chen, S. C., & Hung, C. W. (2016). Elucidating The Factors Influencing The Acceptance of Green Products: An Extension of Theory of Planned Behavior. *Technological Forecasting And Social Change*, 112, 155-163. https://doi.org/10.1016/j.techfore.2016.08.022

Çevikkol, E., Çam, M.A., & Yılmaz, Ö.F. (2023). *Çiftlik Hayvanları Yetiştiriciliğinde Refah ve Stres Kavramı.* ISPEC 11th Internatıonal Conference on Agriculture, Animal Sciences and Rural Development, 03-05 March, Muş. 478-488.

Demir, N. (2012). AB ve Türkiye'de Hayvancılık Politikalarındaki Son Gelişmelerin Uyum Süreci Açısından Karşılaştırılması. *Alinteri Journal of Agriculture Science*, 23(2), 58-63.

Dixit, S., Yadav, A., Dwivedi, P. D., & Das, M. (2015). Toxic Hazards of Leather Industry And Technologies To Combat Threat: A Review. *Journal of Cleaner Production*, 87, 39-49. https://doi.org/10.1016/j.jclepro.2014.10.017

Duran, Y., & Çayın, M. (2026). Tarımsal ve Hayvancılık Desteklemelerinin Kırsal Kalkınmaya Etkisi: Batman İli için Bir Araştırma. *KSÜ Tarım ve Doğa Dergisi* 29 (5), 1307-1319. https://doi.org/10.18016/ksutarimdoga.vi.1764406

Ebrahiem, M. A., Ali, M. A., Turki, I. Y., Haroun, H. E., Bushara, I., & Mekki, D. M. (2015). Defects And Grading Of Hides And Skins İn Kordofan Region, Sudan. *The Journal of Agriculture and Natural Resources Sciences*, 2(2), 393-400.

Er, H., & Erol, E. (2025). *Deri Endüstrisinde Sürdürülebilirliğin Üç Ayağı: Hammadde (İşlenmemiş Deri) Kaynaklı Çevresel Ayak İzinin Literatür Tabanlı Değerlendirmesi.* (Editör: K. Kızıl Erol). Küresel Deri ve Tekstil Ekosistemi Duyusal Pazarlamadan Davranışsal Ekonomiye, Vergiden Sürdürülebilirliğe, Serüven Yayınları, Ankara, s.23-39.

Ergün, O. F., & Bayram, B. (2021). Türkiye'de Hayvancılık Sektöründe Yaşanan Değişimler. Bahri Dağdaş *Hayvancılık Araştırma Dergisi*, 10 (2): 158-175.

FAO, (2022). *Food Loss and Food Waste*. http://www.fao.org/food-loss-and-food-waste/en. (access date: 10.04.2026).

Greenwell, M., Sarker, M., & Rahman, P. K., (2016). "Biosurfactant Production and Biodegradation of Leather Dust From Tannery", The Open *Biotechnology Journal*, 10(1), pp.312-325. https://doi.org/10.2174/1874070701610010312

Güler, O. (2025). *Sürdürülebilir Hayvansal Üretim: Karbon Ayak İzinin Azaltılmasında Zootekni Uygulamalarının Rolü.* (Editör: G.Merhan Muğlu), Disiplinlerarası Yaklaşımlarla Karbon Ayak İzi-I, Efe Akademi Yayınları, İstanbul, s. 177-201

Gürgür, H. (2016). *Eylem Araştırması*. (Eds. A. Saban & A. Ersoy), Eğitimde Nitel Araştırma Desenleri (sf. 3-48) Anı Yayıncılık.

İşler, H. & Ören, H. G. Ü. (2021). Dünya'da, bölgelerde ve Türkiye'de Hayvancılık Sektörü. *Sosyal ve Beşerî Bilimler Araştırmaları Dergisi,* 22(48), 72-95.

Kalkan, A. (1963). Hypodermosis'in Hayvan Endüstrisinde Sebep Olduğu Kayıplar. *Etlik Veteriner Mikrobiyoloji Dergisi*, 2(1), 30-37.

Kanagaraj, J., Senthilvelan, T., Panda, R.C., & Kavitha, S., (2015). Eco-friendly waste management strategies for greener environment towards sustainable development in leather industry: a comprehensive review, *journal of Cleaner Production*, pp.1-17. https://doi.org/10.1016/j.jclepro.2014.11.013

Karaoğlu, M, Macit, M., & Kaya, A. (2023). *Yüksek Rakımda Mera Hayvancılığının Ruminantlarda Ürün Kalitesine Etkisi.* (Editör: G. Erener, A. Altıntop), Hayvan Beslemede Güncel Yaklaşımlar I, Efe Akademi Yayınları, İstanbul, s. 299-386.

Kılıç, B. (2025). Türkiye'de Hayvancılık Sektöründeki Yönetsel Sorunların Görünümü. *Publicus*, (4), 109-155. https://doi.org/10.65911/cb5f1e02

Krishnamoorthy, G., Sadulla, S., Sehgal, P. K., & Mandal, A. B. (2012). Green Chemistry Approaches To Leather Tanning Process For Making Chrome-Free Leather By Unnatural Amino Acids. *Journal of Hazardous Materials,* (215-216), 173-182. https://doi.org/10.1016/j.jhazmat.2012.02.046

Krishnamoorthy, G., Sadulla, S., Sehgal, P. K., & Mandal, A. B. (2013). Greener Approach To Leather Tanning Process: D-Lysine Aldehyde As Novel Tanning Agent For Chrome-Free Tanning. *Journal of Cleaner Production,* 42, 277-286. https://doi.org/10.1016/j.jclepro.2012.11.004

Leach, I., Wilson, T. (1995). Hides and skins for the tanning industry (Vol. 123). Food & Agriculture Org. https://www.fao.org/4/i0523e/i0523e.pdf

Mazak, A., & Kratzwald, B. (2014). *The Weighted Decision Matrix: tracking design decisions in service compositions.* In 2014 IEEE 7th International Conference on Service-Oriented Computing and Applications (pp. 169-174). IEEE. https://doi.org/10.1109/SOCA.2014.55

McQuillan, H. (2011). *Zero-Waste Design Practice: Strategies and Risk Taking For Garment Design*. (Eds. Alison Gwilt and Timo Rissanen), Shaping Sustainable Fashion: Changing the Way We Make and Use Clothes, Earthscan LLC, Was- hington, USA, 83-99.

Mella, B., Glanert, A. C., & Gutterres, M. (2015). Removal of Chromium From Tanning Wastewater And Its Reuse. *Process Safety and Environmental Protection*, 95, 195-201. https://doi.org/10.1016/j.psep.2015.03.007

Navarro, D., Wu, J., Lin, W., Fulyana-i-Palmer, P., & Puig, R. (2020). Life Cycle Assessment And Leather Production. *Journal of Leather Science and Engineering*, 2(1), 1-13. https://doi.org/10.1186/s42825-020-00035-y

Niinimäki, K. (2013). *Sustainable Fashion*: New Approaches. Aalto University Publication. Helsinki, Finland.

Ocakoğlu, N. (2018). Giysi Tasarımına Yenilikçi Yaklaşımlar. *The Journal Of Academic Social Science*, 83(83), 539-551. https://doi.org/10.16992/ASOS.14486

Ortega, L. M., Lebrun, R., Noël, I. M., & Hausler, R. (2005). Application of Nanofiltration in The Recovery of Chromium (III) From Tannery Effluents. *Separation and Purification Technology*, 44(1), 45-52. https://doi.org/10.1016/j.seppur.2004.12.002

Özdemir, M., & Kayabaşı, N. (2007). *Geçmişten Günümüze Dericilik*, T.C. Kültür ve Turizm Bakanlığı Yayınları, Ankara.

Özgünay, H., Çolak, S., Zengin, G., Sari, O., Sarıkahya, H., & Yüceer, L., 2007. "Performance and Emission Study of Biodiesel From Leather Industry Pre-Fleshings", *Waste Management*, 27(12), 1897-1901. https://doi.org/10.1016/j.wasman.2006.08.014

Özkan, G. (2024). Katma Değerli Tarım, Döngüsel Ekonomi ve Sürdürülebilir Kalkınma: Ekonomik, Çevresel ve Sosyal Perspektifler. *Journal of Environmental and Natural Studies*, 6 (3), 288-299. https://doi.org/10.53472/jenas.1587727

Paschoal, F. M. M., Anderson, M. A., & Zanoni, M. V. B. (2009). Simultaneous Removal of Chromium And Leather Dye From Simulated Tannery Effluent By Photoelectrochemistry. *Journal of Hazardous Materials*, 166(1), 531-537. https://doi.org/10.1016/j.jhazmat.2008.11.058

Pringle, T., Barwood, M., & Rahimifard, S. (2016). The Challenges in Achieving A Circular Economy Within Leather Recycling. *Procedia CIRP*, 48, 544-549. https://doi.org/10.1016/j.procir.2016.04.112

Sathish, M., Madhan, B., Sreeram, K. J., Rao, J. R., & Nair, B. U. (2016). Alternative Carrier Medium for Sustainable Leather Manufacturing–a Review and Perspective. *Journal of Cleaner Production*, 112, 49-58. https://doi.org/10.1016/j.jclepro.2015.06.118

Statistics PASW. (2009) Predictive Analytics SoftWare Statistics (Version 18). SPSS Inc.

Thanikaivelan, P., Rao, J. R., Nair, B. U., & Ramasami, T. (2005). Recent Trends in Leather Making: Processes, Problems, and Pathways. *Critical Reviews in Environmental Science And Technology*, 35(1), 37-79. https://doi.org/10.1080/10643380590521436

TUIK. (2025). *Livestock statistics* https://veriportali.tuik.gov.tr/tr/press/58015 (access date: 10.04.2026).

Valentin, S. O., Victoria, A., A., Sabina, G., & Marius S. U. (2014). "Management of Pro- cessing and Recovery of Leather Waste", *Fascicle of Textiles,* 15(2), 157-162.

Yıldırım, A., & Şimşek, H., (2013). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*, (9. bas.) Seçkin Yayıncılık, Ankara.

Yıldız, B., & Kütahyalı, D. N. (2021). Yeşil Ürün Tutumunun Yeşil Satın Alma Niyeti, Geri Dönüşüm ve Yalın Tüketim Üzerindeki Etkisi. *Bingöl Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 5(1), 365-398. https://doi.org/10.33399/biibfad.875298

Zuriaga-Agustí, E., Galiana-Aleixandre, M. V., Bes-Piá, A., Mendoza-Roca, J. A., Risueño-Puchades, V., & Segarra, V. (2015). Pollution reduction in an eco-friendly chrome-free tanning and evaluation of the biodegradation by composting of the tanned leather wastes. *Journal of Cleaner Production*, 87, 874-881. https://doi.org/10.1016/j.jclepro.2014.10.066