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Raw Sheep Wool Management for Thermal Insulation Materials: The Case of Lithuania

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ABSTRACT

Raw sheep wool preparation processes are closely related to the use of environmentally harmful raw materials. To solve this problem, alternative ways of cleaning wool, often called environmentally friendly, are being sought. In this research, the possibilities of using Lithuanian wool for the production of thermal insulation materials were investigated. For this purpose, 4 tons of raw wool of different breeds of sheep was selected from various Lithuanian sheep breeders' farms. Sources of impurities in wool were identified and the amount of fat in wool was assessed. After the initial re-selection, the wool was washed in different modes and with different detergents. The recycled and washed wool was supplied to the factory for the production of thermal insulation material.The aim of this work is to identify the main sources of wool impurities, analyze the quality of wool of different sheep breeds from different farms and evaluate the washing efficiency of different detergents and methods for different sheep breeds wool, and evaluate the quality of prepared wool raw material during different actual production processes. The results of the research provide preconditions for the improvement of thermal insulation materials of the sheep wool production and its quality management.

摘要

羊毛原料的制备过程与使用对环境有害的原料密切相关. 为了解决这个问题, 人们正在寻找清洁羊毛的替代方法, 通常被称为环境友好型. 在这项研究中, 研究了使用立陶宛羊毛生产隔热材料的可能性. 为此, 从立陶宛各绵羊养殖场挑选了4吨不同品种的绵羊原毛. 确定了羊毛中杂质的来源, 并评估了羊毛中的脂肪含量. 在最初的重新选择之后, 羊毛以不同的方式和不同的洗涤剂洗涤. 回收和洗涤的羊毛被供应给工厂用于生产隔热材料. 这项工作的目的是确定羊毛杂质的主要来源, 分析来自不同农场的不同绵羊品种的羊毛质量, 评估不同洗涤剂和方法对不同绵羊品种羊毛的洗涤效率, 并评估在不同实际生产过程中制备的羊毛原材料的质量. 研究结果为羊绒生产中保温材料的改进和质量管理提供了前提条件.

KEYWORDS

Raw sheep wool; sheep breeds; wool washing; fat content; wool impurities; production of thermal insulation material

关键词

关键词; 生羊毛; 绵羊繁殖; 洗羊毛; 隔热材料的生产

Introduction

There are about 1.173 billion sheep in the world, with a population of about 850 breeds (EFSA 2014). Almost four dozen breeds of sheep are bred in Lithuania, but there are three main breeds of sheep: Lithuanian black-heads, and Romanov and Lithuanian local coarse-grained (LSD 2020). Sheep are reared in Lithuania for several reasons – for meat, for the care of parks and other areas, for fur, and probably, at the least for wool. Meanwhile, wool is one of the main sources of sheep production in sheep farms in the world. In 2017, there were 348.126 tons of wool exported worldwide (RB 2018).

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Another important part of the production is sheep meat. In 2013, sheep accounted for about 3% of total world meat production. Most parts of the wool and lamb are obtained in Asia and Africa (RB 2018; Speijers et al. 2015). Almost all sheep products raised in Lithuania are consumed in the domestic market. At present, a relatively small number of sheep is bred in Lithuania – 152 thousand (Melnikienė, Kriščiukaitienė, and Namiotko 2020). Meanwhile, in the interwar period, about 1.5 million of sheep were grown in Lithuania (ZUM 2016).

The biggest problem that hinders the development of the use of sheep wool is the processing of raw wool. There is no primary industrial processing of sheep wool in Lithuania. The obtained raw wool is used only in a few small Lithuanian companies, where the wool is washed partially by hand and in very small quantities – from a few kilograms to several hundred kilograms per day. All wool is cyclically washed with warm water or warm soapy water. Washed wool is commonly used in the manufacture of yarns, fabrics, felts, and padding. There is no precise information on the amount of wool to be washed in Lithuania, but according to general data, it can be concluded that only about 3–8% of the total wool is washed. Other remaining wool is burned, composted, or stored in warehouses for a number of years. A very small portion of wool is sold to neighboring countries.

According to Allafi et al. (2021a), sheep wool contains high levels of impurities. The impurities on the surface of raw wool fiber need to be removed through cleaning processes. The quality and price of wool depend on the chosen washing method. In the textile industry, wool is usually washed with the help of water using a variety of chemicals, resulting in large amounts of contaminated water. It is estimated that between 17% and 20% of all contaminated industrial water is obtained from the textile processing (EP (European Parliament) 2018; Kant 2012). In order to meet environmental requirements, all used water must be treated, which is a costly technological process. According to Ghaly et al. (2014), 200 l of water is used to prepare 1 kg of wool for textile industry. As a result, the supply of wool to textiles in Europe has been declining for the third decade (EP 2020). Although sheep farming has grown by around 10% worldwide over the last two decades, wool production has still fallen by around 10% (Skapetas and Kalaitzidou 2017).

In the textile industry, the quality of wool is assessed in terms of fiber diameter, straightness (corrugation), yield, color, amount of impurities, staple strength, and length. Fiber diameter is the most important indicator that determines the quality and price of wool (Gleba 2012; Turgenbaev and Rusakov 2019). According to various scientific studies, wool of various sheep breeds and qualities can be used for the production of thermal insulation materials (Denes, Florea, and Manea 2019; Patnaik et al. 2015; Zach et al. 2012). In this way, wool quality indicators and leaching indicators are less important than in the preparation of wool for the textile industry, which reduces the cost of raw material preparation. Although there are no companies in Lithuania focused on the production of thermal insulation materials from sheep wool or other natural fibers, after several modernization processes, such products could be produced by several textile processing companies. Modernization processes should include the selection of more powerful fibers openers and the use of coarser wires in the drums and rollers of the carding machine.

Despite the lower requirements for the raw material, sheep's wool still needs to be thoroughly cleaned and washed. Most authors cite common sources of impurities in wool: fats, moisture, sweat, dust, and other organic and mineral impurities (Allafi et al. 2021a; Ahmed, Qayoum, and Mir 2019; Fiore, Di Bella, and Valenza 2020). It is often noted that wool quality and sources of impurities are highly correlated with sheep body parts. Typically, sorting wool is divided into fiber parts of different quality from different parts of the body. The highest quality wool that can be used for textiles is obtained from the shoulders and sides of sheep; inferior wool is obtained from the calves and used to make carpets. The wool from the back end of the sheep, their legs, and sometimes their belly is too full of manure to use. These are referred to as "tags" (as in the phrase "tag end"). These are removed first before washing the fleece; this process is called skirting, as all the edges of the wool coat are removed. The fleeces are also sorted into various types: fine from coarse and short from long (Ajay, Prince, and Jose 2017; Bouagga et al. 2020; Scobie et al. 2015).

Table 1. Description of sheep productivity data and fiber characteristics LSMU (institute of animal science of LUHS) 2006.

Breed of sheep	Groups of sheep	Sheep weight, kg	Sheared wool per year, kg	Average length of wool fibers, mm	Average diameter of wool fibers, µm
Skudde (coarse heterogeneous wool)	Breeding rams	40–50	2.0–2.5	100 ÷ 120	29 ÷ 33
	Ewes	30–40	1.2–2.0		
	Annual lambs	30–40	1.5–2.0		
	Annual ewes	25–35	1.0–1.8		
German black-heads (semi-fine wool)	Breeding rams	110–135	5.0–7.0	80 ÷ 100	32 ÷ 35
	Ewes	75–85	4.0–5.0		
	Annual lambs	60–80	3.0–4.0		
	Annual ewes	50–60	2.5–3.5		
Lithuanian black-heads (semi-fine wool)	Breeding rams	85–95	4.5–5.5	80 ÷ 100	28 ÷ 33
	Ewes	60–70	2.5–3.5		
	Annual lambs	50–60	2.5–3.5		
	Annual ewes	40–50	1.5–2.5		
German Merinolanschaf (fine wool)	Breeding rams	120–140	6.0–10.0	70 ÷ 90	22 ÷ 28
	Ewes	90–100	5.0–8.0		
	Annual lambs	70–80	4.0–6.0		
	Annual ewes	60–70	4.0–6.0		

The aim of this work is to identify the main sources of impurities in wool, to analyze the quality of different sheep breeds wool from different farms, to evaluate the effectiveness of different detergents and methods for different sheep breeds wool, and to check the suitability of prepared wool for thermal insulation in real factory conditions.

Materials and methods

Description of sheep wool

Wool of four sheep breeds were used in the current research: Skudde, German black-heads, Lithuanian black-heads, and German Merinolandschaf. The following is a description of sheep species according to the information collected by Institute of Animal Science of LUHS LSMU (Institute of Animal Science of LUHS) 2006.

Skudde breed sheep. Sheep of this breed is also known as Masurian and farmer sheep – belong to the Northern Short-tailed Sheep Group. They come from East Prussia, Lithuania, and other Baltic countries. These sheep have a wedge-shaped head, coarse wool, and horns of various lengths. Sheep wool is usually white, less common is black or brown. Productivity data for sheep breed are presented in Table 1.

Skudde wool is suitable for both felting and spinning, it fascinates with its natural colors and moss-like mohair wool, and the wool itself, depending on the sheep, can be straight or can be tied in strands. And this is very much appreciated by wool felters.

German black-heads sheep. These are fast-growing, well-defined fleshy sheep, with a deep, broad chest, long back, fleshy inner and outer sides of the ham, and very good carcass quality. The head and legs are black, the forehead is covered with wool, and the body is strong. The direction of productivity is developing – meat and wool.

The purpose of the breeding is to raise large, early-maturing beef sheep with pronounced meat forms and high fertility. Productivity data for this breed of sheep are presented in Table 1.

Lithuanian black-heads sheep. The head of this breed of sheep is short, broad, and straight in profile. The head, legs, and ears are covered with black hair, but the head up to the line of the ears, and the legs up to the line of knees and heels, are covered with white wool. The hair of the head and legs of newly born lambs is black, the body is overgrown with gray-brown hair of various intensities, which falls out before weaning, and the hair typical of the breed grows in its place. Productivity direction is developed – meat and wool. The wool of adult sheep is 25–34 microns thick, of suitable density, the hair is white and yellowish, and the belly is overgrown wool.

The purpose of breeding: to preserve the gene pool of the Lithuanian black-head breed. Selection is carried out to increase the meatiness and fertility of the animals. Breeding is carried out by pure breeding, infusing the blood of more productive rams (German black-heads, Suffolk, etc. breeds) of the same productivity direction in one generation. Productivity data of Lithuanian black-heads sheep are presented in Table 1.

German Merinolandschaf sheep. These are medium-sized and large sheep used for meat and wool. Depending on the sex, the head is medium-sized, broad, and overgrown to the line of the eyes.

Horniness is undesirable. Description of body composition: deep, broad chest, long, firm, and muscular back, broad, low waist, and fully defined inner and outer sides of the ham. Thin and white wool is characteristic of the Merino variety; the fineness of wool reaches 22–28 microns. Skin wrinkles are undesirable.

The purpose of breeding: to breed medium-sized to large sheep for meat and wool, with well-defined meat production, off-season fertility, and good forage uptake and a good constitution. German meat merino wool should be of high quality, curly, and pure white. Productivity data for German Merinolandschaf sheep are presented in Table 1.

Selection of sheep wool and assessment of impurities

Sheep wool was purchased from Lithuanian farmers' farms. 4 tons of un-selected and uncleaned sheep wool was sampled. Wool of four sheep breeds were used in the research: Lithuanian blackheads, German blackheads, German Merinolandschaf, and Skudde. All wool raw materials were manually re-selected to separate wool from foreign matter. Sources of impurities were assessed visually; the main systemic and random sources were distinguished. Possible sources of impurities were discussed with farmers and the causes of they were assessed.

Washing of sheep's wool

The selected and re-selected wool raw material of each sheep breed was placed in plastic baths of 20 kg each. The average thickness of the wool layer supplied for washing was 50 cm. The wool raw material placed in the baths is filled with water with or without the selected detergent. Two main washing criteria were chosen: soaking time and type of detergent. Washing with water without detergents only, washing with soap, and washing with detergent with probiotics were chosen. Washing was performed in three or four cycles. During the first cycle, the wool is soaked in water and mixed for 10 minutes. After mixing, the wool is left to soak for a set period of time. The second cycle then begins. The soaked wool is stirred again for 10 minutes and the dirty water is drained. The wool is then refilled with clean water and mixed for 10 minutes. After mixing, the dirty water is drained again and the second cycle is completed. The third cycle is the same as the second, only after the third cycle is a visual assessment of the need for a fourth wash cycle based on water contamination. If the water is clear after three cycles, then the wash is completed, and if the water is turbid, then a fourth cycle is performed. The duration of one cycle consists of filling with water (5 min), mixing of wool (10 min), soaking of wool (from 40 min to 23 h 40 min), and draining of water (5 min). After washing, the wool is placed in a centrifuge drum and centrifuged at 800 rpm for 12 minutes to remove most of the water.

Evaluation of sheep wool washing quality

The washing quality of sheep's wool is assessed by determining the content of non-fibrous matter (oils, fats, and waxes) GOST (Governmental Standard) 1979.

Quality assessment of sheep wool ready for production

The prepared sheep's wool is tested under real conditions by forming a thermal insulation product in the factory. During production, three main criteria are evaluated: the raw material opening rate, the raw material carding rate, and the layer sintering rate. The qualitative performance of the wool itself is not assessed, as the rate of raw material opening; carding and sintering depend on the ability of equipment to ensure a smooth production process, the accumulation of grease, and other impurities in individual production line units, and the need for periodic cleaning.

Results and discussion

Sources of impurities

As there are no industrial wool processing workshops in Lithuania, wool obtained on farms is not sorted. For this reason, different layers of wool are mixed together and the whole raw material is affected of several sources of impurities. The following sources of impurities have been identified during the selection and washing of wool, which complicate the wool washing process and degrade its quality:

- Sheep feces;
- Weeds (mainly burdock and beggar ticks);
- Insects (mainly cockchafers and mealworms);
- Intertwined wool threads;
- Fats;
- Accidental impurities.

Sheep feces. As temperatures in Lithuania are relatively low during the cold period, sheep are kept indoors on litter. As a result, the feces get into the individual layers of wool. For this reason, sheep owners usually organize sheep shearing once a year before the cold season (according to some authors (Malik et al. 2021), conversely – in the spring), i.e. before letting the sheep indoors. However, even this method of protection is not fully effective. As the autumn-winter weather in Lithuania is very variable – rain/wet-sun and low-high temperatures, it determines not only the formation of wet soil but also increases the fecal impurities of individual sheep wool layers due to higher adhesion. The area of wool that is most contaminated with feces is in the belly of sheep.

Weed impurities. All collected samples of sheep wool from farms dominated by perennial meadows. This means that herbaceous plants are not renewed as well weed control measures are not used. Two types of weed seeds were found in all samples – burdock (in Latin – Arctium) and beggarticks (in Latin – Bidens). By manually picking the wool, only most of the weed seeds are removed. It is still not possible to remove some of the seeds as they are crushed and spread over a large volume of wool. The area of wool where most of the weed seeds are found is on the sides of the sheep.

Insects. Many cockchafers (in Latin – Melolontha melolontha) and mealworms (in Latin – Tenebrio molitor) are found in the raw material of sheep wool. This is likely to be related to sheep rearing in perennial, less regenerating, meadows. Such meadows are intensively breeding, so both in late summer and early autumn, beetles crawling in the meadow easily penetrate the longer coat and remain until the end of the cold season, as the structure of beetles – hair, bristles, and limbs – is very favorable for wool scales.

Intertwined wool threads. The darker tips of the fleece are the "outside" furthest from the animal's skin. This is the area that rubs in the dirt and the prickles. Some sheep hairdressers cut these strands.

Fats. Sheep's wool naturally produces a large amount of fat. This amount varies constantly depending on the seasons and the housing conditions of the sheep. More detailed information on the fat content of sheep wool is provided in the following sections.

Accidental sources of impurities. A number of additional sources of impurities that get into the wool due to poor sheep housing, shearing conditions, or storage of sheared wool needs to be addressed. If sheep are reared in a dirty environment, various metal and plastic wastes can get into the wool – pieces of wire, scraps of plastic parts, etc. If sheep are sheared in unprepared places, so the wool is mixed with hay and litter. If sheared wool is stored in open bags in unsuitable places, a lot of dust, straw, bedding, and other debris pass through the top of the bag. In addition, various rodents, insects, and worms are found.

Washing of raw wool

The washing process was chosen to taking into account the requirements of environmental friendliness. Two main washing criteria were chosen: soaking time, and detergent. Further details on sheep wool, detergents and their quantities, washing time and number of cycles are given in Table 2.

Evaluation of raw wool washing quality

A chaotic set of results was obtained after 336 units of wool washing tests (Figure 1).

This shows that the quality of wool washing is determined by many factors. The wool washing results of individual samples differ more than 10 times. The results were grouped to determine interdependencies. The fat content of wool was first distinguished by sheep breeds (Figure 2). The grouping of the results showed that wool from sheep of each breed has its own characteristics. Insufficient data have been found in the literature describing how the purity and fat content of individual wool species depend on sheep farming conditions. The results of sheep wool washing allowed distinguishing wool groups according to their fat content. It should be emphasized that the initial washing of the wool was carried out with water in order to remove impurities of various origins and to allow a more accurate assessment of the fat content of the wool. Thus, in this case, the washing with water was not so much more important for the assessment of fat than for the deduction for the

Table 2. Wash cycles and wash times of raw sheep wool.

The breed of sheep from which the raw wool was obtained	Detergent	Detergent concentration	Duration of the first cycle, hrs	Total number of cycles of the respective type of sheep wool, pcs
Lithuanian black-heads/ German black-heads/ German Merinolandschaf/ Skudde/	Wash only with water without detergent	-	24 16 8 1	4/ 3/ 3/ 3
	Washing with liquid soap	Recommended by the manufacturer	24 16 8 1	
		50% lower than recommended by the manufacturer	24 16 8 1	
		50% higher than recommended by the manufacturer	24 16 8 1	
	Washing with detergent with probiotics	Recommended by the manufacturer	24 16 8 1	
		50% lower than recommended by the manufacturer	24 16 8 1	
		50% higher than recommended by the manufacturer	24 16 8 1	

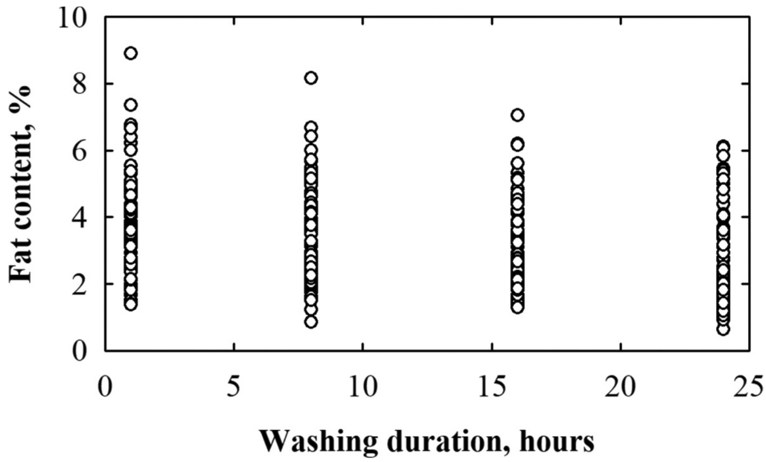

Figure 1. Overall results of the fat content of the wool for different durations of washing.

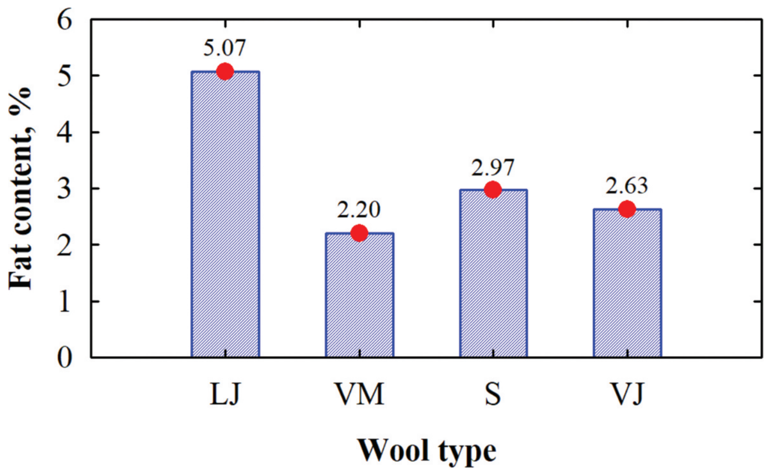

Figure 2. The fat content of the wool by the breed of sheep: LJ – lithuanian black-heads; VM – German merino; S – skudde; VJ – German black-heads.

assessment of the initial fat content. Analysis of the results showed that German merino wool has the lowest fat content. This wool also looked visually clean, with the least amount of dirt and other impurities.

Meanwhile, the wool of Lithuanian black-heads sheep had a bright gray hue, and during washing, it required as many as 4 washing cycles due to extremely dirty water after the first washing cycle and visually visible contaminated water after 2 and 3 cycles. It is in this wool that the fat content is about twice as high as in other sheep breeds wool. German black-heads sheep wool had no special features before washing and was visually similar to German merino wool. Meanwhile, wool of the Skudde breed showed higher entanglement than the wool of other types but did not show higher number of dirt and other impurities.

The results were further grouped according to the washing time (Figure 3). The data in Figure 3 show that the washing times of 16 and 24 hours allowed to significantly increase the intensity of fat washing – a reduction of almost 30% of the fat content compared to the washing times of 1 and 8 hours. Longer wash times have been abandoned because of the likely onset of intense bacterial growth and the formation of a particularly unpleasant and long-lasting odor in the environment.

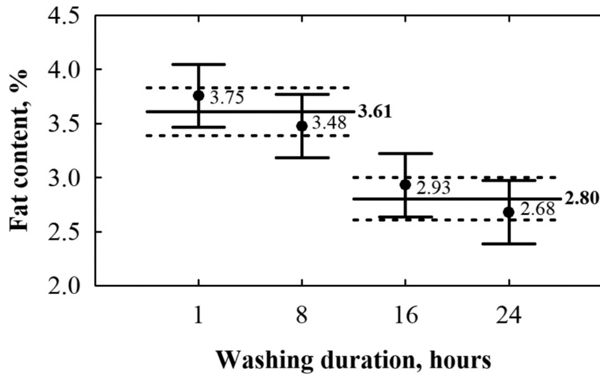

Figure 3. The fat content of sheep wool by washing time.

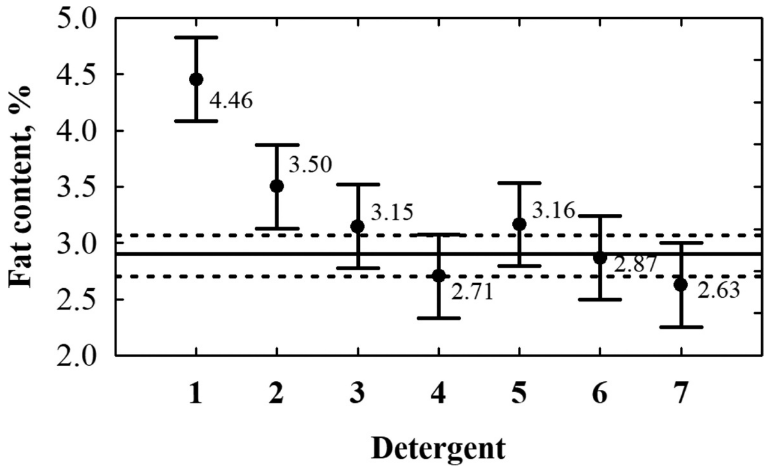

Figure 4. Distribution of the fat content in sheep's wool by type of detergent and its amount when washing: 1 – with water only; 2 – soap, when 50% less than recommended by the manufacturer is used; 3 – soap, when the manufacturer's recommended amount is used; 4 – soap when 50% higher than recommended by the manufacturer is used; 5 – detergent with probiotics, when 50% less than recommended by the manufacturer is used; 6 – detergent with probiotics, when using the amount recommended by the manufacturer; 7 – detergent with probiotics, when 50% higher than recommended by the manufacturer is used.

Subsequently, the results were grouped by detergent type (Figure 4). Analysis of the results shows that the amount of fat remaining in the wool also depends on the type and amount of detergent. Washing with soap and probiotics and using increased their amounts showed the best fat leaching results. Due to the unequal initial impurities in wool, it is not possible to clearly distinguish the advantage of probiotics over soap. In the general context, a very small advantage of probiotic detergent over soap is observed, but it is unclear whether it is due to the unevenness of the raw material or to the effectiveness of the detergent.

Table 3. Changes in raw wool mass after different washing number cycles.

Duration of the first cycle, hrs	Weight loss of wool after the first wash cycle, % by mass	Total weight loss of wool after the second wash cycle, % by mass	Total weight loss of wool after the second wash cycle, % by mass
24	33.0	35.4	36.0
16	31.2	33.1	35.2
8	25.7	30.2	33.8
1	22.3	28.1	33.7

The weight loss of raw wool after different washing cycles is shown in Table 3. German black-head wool was selected for comparison. The washing was carried out using a detergent with probiotics and at a concentration of 50% higher than recommended by the manufacturer. The results of the research show that the initial weight loss of the raw wool material is mainly dependent on the initial soaking time. When the raw material is soaked for 24 hours, the weight loss of the raw wool after the first cycle is the largest, about 33%. Similar results are observed after 16 hours of soaking. After 1 hour and 8 hours of soak, the weight loss of raw wool after the first cycle is approximately 25% lower than with 16 and 24 hours of soak. After the second and third cycles, a greater weight loss was observed for the samples soaked for 1 hour and 8 hours, resulting in a maximum total difference of 2.3% between all samples after the last cycle.

Factory processing of washed wool

All the prepared raw material was delivered to the factory for the production of thermal insulation material. At the plant, three main processes were identified that influenced the production rate of the thermal insulation material: the raw material opening rate, the raw material carding rate, and the hardening rate of the prepared layer. These three processes determine the required purity of the raw material and at the same time the production speed. Wool of four sheep breeds with different fat contents ≤2%, ≤3%, ≤4%, and ≤5% were delivered to the plant. The main stages of production of thermal insulation material from sheep wool are presented in Figure 5. At the plant, sheep wool was first opened to separate the fibers and the impact of existing sources of impurities on the efficiency of this technological process was assessed. This process is complicated by residual weeds, twisted wool tufts, and fats. The higher the quality of the opening process, the less polluted and twisted the wool is, the higher the quality of the further technological process – carding. The quality of wool carding is mainly influenced by weeds left after opening and large twisted tufts of wool. During carding, the carder needles make it difficult to comb the wool, which has a lot of remaining dirt or twisted wool. The wool obtained after carding is pulled out, without large objects of impurities. During this technological process, dirt falls off, but the wool still retains a very small amount of dirt. After carding, the formation and hardening of the layer begin.

The fat remaining in the wool has the greatest influence on the hardening process and quality of the layer. In larger quantities, during the heat treatment, fat is incinerated and a large amount of smoke is emitted, and the cardigans themselves are difficult to bond with each other. This is especially evident in the surface layer, where peeling of the upper layer from the rest of the product is visible. When the fat content of the wool does not exceed 3%, this problem is not observed or is observed very rarely.

Discussions

Summarizing the results, it can be stated that Lithuanian wool is characterized by increased foreign matter from all sources of impurities. To a large extent, the increased foreign matter is caused by natural conditions: changes in climatic conditions (rain, sun), the predominant soil on which sheep graze, and growing vegetation. However, on-farm sheep housing, wool shearing, and storage conditions also have a significant impact. There are no precise data on the extent to which the fat content of the wool is determined by the housing conditions of the sheep, the time of shearing, or the breed of the sheep. In most Lithuanian sheep farmers, sheep are not reared for the wool they receive, so they pay little attention to their quality. Several scientific studies indicate that the quality of wool is most closely related to sheep breed, age, nutrition, climatic conditions, grass impurities, mud and feces, and so on (Allafi et al. 2021a; Cholewinska et al. 2020; Khan et al. 2012). There is no more detailed information on the requirements for grassland care, sheep housing, shearing process and sorting, shearing location, storage of sheared wool and the impact of these factors on wool quality.

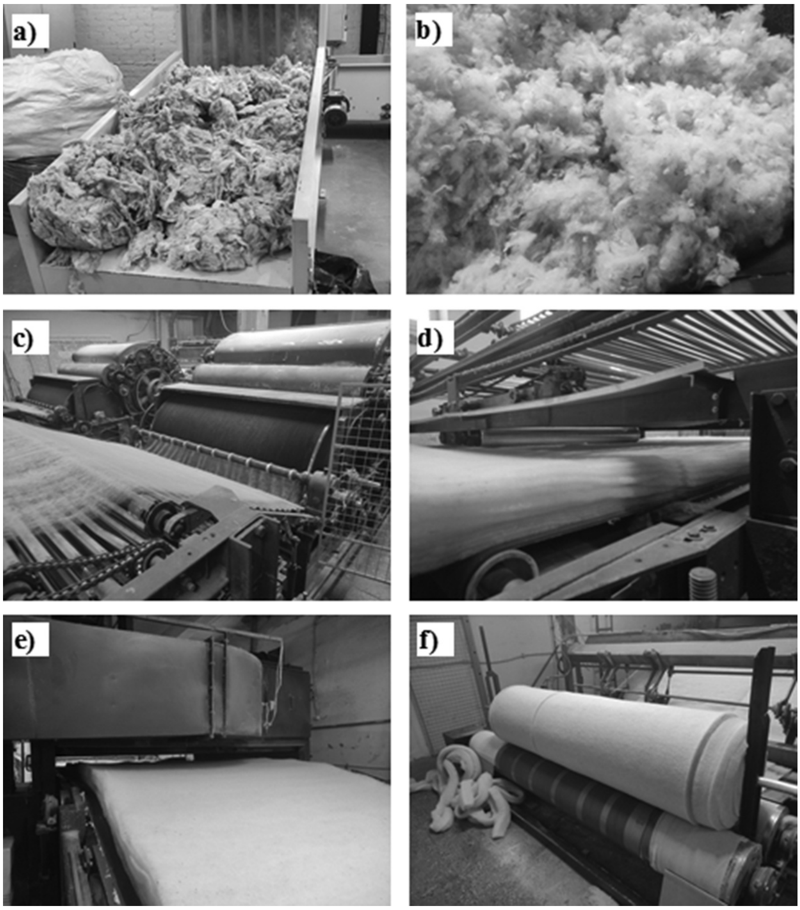

Figure 5. The main stages of the production of thermal insulation material from sheep wool: a – supply of prepared wool to the production line; b – scribbled wool in a bale opener; c – manufacture of single layers from carded wool; d – manufacture of semi-finished product from single layers; e – supply of semi-finished product to the curing chamber; f – cutting and winding of the prepared product.

Another important highlight is related to the wool cleaning methods. Many of the authors' works focus on new cleaning methods such as, supercritical CO2 utilization, pulsed electrohydraulic discharge, washing with ultrasound and the like (Allafi et al. 2021b; Bahtiyari and Duran 2013; Zhang et al. 2016). Since the use of sheep wool for the production of thermal insulation materials does not require the provision of high-quality and high-purity wool raw material, simple and economically cheaper methods for cleaning raw wool can be used. This allows the use of environmentally friendly detergents and lower temperature water. The lower requirements for raw wool for the production of thermal insulation materials are also confirmed by the works of other authors (Ghermezgoli et al. 2021; Ahmed, Qayoum, and Mir 2019; Bosia et al. 2015), which indicate that sheep wool waste can be used for the production of thermal insulation material.

Conclusions

(1) The final quality of washed wool depends largely on the foreign matter in the raw material. Lithuanian raw wool is characterized by increased foreign matter both due to climatic conditions and due to insufficient attention paid to preserving the quality of raw wool.

(2) Adjusting the washing time allows to get cleaner wool with less detergent. With the same amount of detergent and by extending the washing time from 1 to 24 hours, the cleanliness (in terms of fat) of wool can be increased by more than 20%. Ambient water and environmentally friendly detergents can be used instead of hot water to avoid expensive energy resources. By using environmentally friendly detergents and selecting the right concentrations, the fat content of sheep's wool can be reduced by about 60%.
(3) For the proper preparation of technical wool, a number of factors must be assessed: the housing conditions of the sheep, the shearing period and conditions, the breed of the sheep, and the adjustment of the washing time, type, and amount of detergent during the washing procedure. In this way, the scattering of the results will be small and the purity of the wool will be sufficient.
(4) Too much fat in the raw wool slows down the production process: equipment clogs, the layer forms poorly, binder hardening deteriorates, and the fat remaining in the wool during the heat treatment of the layer begins to burn, resulting in a large amount of smoke. Problems do not occur during production if the fat content of the wool does not exceed 3%.
(5) The results of the research show the importance of preparation in the stages of the sheep wool to produce thermal insulation materials, the advantages of the used processes and the stages to be improved, provide preconditions for the improvement of the production and it‘s quality management.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Highlights

The sources of impurities in raw wool are related to all stages of the raw material preparation.
The washing of raw wool can be conducted with a lower impact on the environment.
Production rate of the thermal insulation material depend on three main factors.

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