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Analysis of the current bedding material situation and assessment of the near-future development outlook in Finland

Katariina Manni, Heidi Högel, Markku Saastamoinen, Lilli Frondelius and Arto Huuskonen

Luke
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Foreword

Currently, the bedding material markets in Finland are experiencing major changes. Fiercer competition for raw materials suitable for use as bedding materials and the pressure to reduce the use of peat are key underlying factors. Concerns about the sufficiency of materials suitable for use as bedding materials and the general cost crisis have increased uncertainty about how to secure the supply of bedding materials in the future. As a result, there was an acute need for a study to comprehensively investigate the use and availability of peat and other bedding materials and to assess their future outlook and related development needs.

In April 2023, Natural Resources Institute Finland (Luke) initiated a project to identify the current bedding material situation from the perspectives of bedding material users and producers. Any changes expected to take place in the bedding material markets in the near future were also assessed. The key goal of this study was to generate an overview of the current situation and future outlook in the bedding material markets, as well as any changes for which we should be prepared.

The study was commissioned by the Central Union of Agricultural Producers and Forest Owners (MTK) and involved the Bioenergy Association of Finland, the milk delegation of MTK, the Professional dairy farmers association, the Finnish Beef Breeders' Association, and the Finnish Broiler Association. All the organisations above provided funding for the study alongside Luke.

The active steering group contributed to the study's progress and provided valuable feedback to support the study. The steering group was chaired by Marjukka Mattio (the milk delegation of MTK), and its members were Mari Lukkariniemi, Saara Patama and Johan Åberg from MTK; Hannu Salo from the Bioenergy Association of Finland; Janne Pitkänen from Biolan Ltd; Henna Mero from the Professional dairy farmers association; Ari Huunonen from Neova Ltd; Tero Hosike and Susanna Heikkinen from the Finnish Beef Breeders' Association; Kalle Mahlamäki from the Finnish Broiler Association; and Hanna Hamina from the Finnish poultry association.

Various operators from the sector participated in the study. We received expert help from individual representatives of associations and companies working with bedding materials. In addition, everyone who responded to the two bedding material surveys, one of which was targeted at bedding material users and the other at producers, sellers and/or importers, gave their valuable input.

The authors would like to thank the funding providers, the members of the steering group and all the partners who participated in conducting the study for their excellent and productive cooperation.

Jokioinen, August 2023

Authors of the report

Abstract

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The bedding material report studied the use and availability of different bedding materials as comprehensively as possible and assessed their related future outlook and development needs in Finland. The report started from the current state of the use and availability of bedding materials. The future development outlook was assessed over a span of five years.

Data collection was based on the literature, official statistics, expert assessments, and surveys conducted during the study, with one targeted at livestock producers and horse sector operators, and the other targeted at producers, sellers and/or distributors of bedding materials. To examine the regional production and use of bedding materials, Finland was divided into four major regions in accordance with the distribution of Centre for Economic Development, Transport and the Environment areas: Southern, Western, Middle and Northern Finland.

Peat is a bedding material used extensively in Finland. However, it is predicted that the sales volumes of bedding peat will halve during the next five years. If this prediction is realised, new materials will urgently be required to replace and supplement peat. What makes this situation even more critical is that there is also a shortage of wood shavings and sawdust used frequently as bedding materials, at least at present, as they are used in energy generation.

In addition to ensuring the availability of bedding materials, it is important to address their cost impact. As bedding is a key part of animal welfare and health, and partly of food hygiene, sufficient and effective bedding cannot be compromised. It is therefore absolutely essential to address the costs arising from bedding as well in ensuring the supply of bedding materials.

To secure bedding material supply in every situation, we need to primarily ensure the availability of current and effective bedding materials, at least until they have effective options with competitive prices and sufficient availability. Launching new materials in the markets takes years, and it cannot lead to a situation where animal welfare decreases due to insufficient bedding resulting from the lower availability of bedding materials and higher prices.

The selection of bedding materials is always a comprehensive farm-specific solution which is affected by the properties required from bedding materials in different situations. When comparing bedding materials, they cannot be ranked in any specific order because they have different properties, and their users' needs also vary. Furthermore, the effectiveness of materials as a bedding material or their volumes cannot be assessed based on individual properties alone, as each bedding material needs to be considered as a whole based on several properties required of bedding materials.

Peat is the most critical bedding material in broiler production. It is difficult to find a bedding material to replace the use of peat in broiler production to secure the high foot health and antibiotic-free production of birds. Materials that replace and supplement peat are already available for cattle, horses, sheep, and pigs. However, their sufficiency is a critical factor, as certain materials are already in short supply. Increased competition is also reflected in

higher prices. This was clearly indicated by the surveys targeted as livestock producers, horse sector operators and bedding industry companies.

Of biomasses produced in fields, straw is the best known and most frequently used bedding material, while not all its potential has yet been used. The use of straw could be increased in cooperation between farms and in large-scale commercial activities. Pelleted straw is good example of commercial-scale solutions, while nearly all pelleted straw is currently imported. There could therefore be potential markets for their domestic production. Increasing the use of straw in bedding materials would lead to larger harvesting areas and longer transport distances than at present.

The potential of slurry and manure as bedding materials has yet to be fully utilised. The cost of separating manure produced on farms into bedding materials is not high after the initial investment. Using recycled manure as a bedding material can increase a farm's self-sufficiency in bedding materials. Currently, solid fraction of separated slurry is only used as bedding materials for cattle. The possible use of separated manure as a bedding material for other animals as well requires research. If the use of recycled manure as a bedding material expands, sufficient quality must be maintained in all conditions. Clear guidelines should be prepared for the use of recycled manure as a bedding material to minimise risks associated with food hygiene and animal health, as has been done in the UK, for example. The significance of hygienic quality will be particularly emphasised if separated manure is transported between farms.

Side streams of the wood and sawmill industry, including wood shavings and sawdust, are significant bedding materials, and their availability as such must be secured. This was a key factor last year, in particular, when competition for availability became fiercer. In addition, the use of other industrial side streams suitable for use as a bedding material should be advanced, as this also supports the circular economy. Forest industry sludge is a good example of this. The potential of natural materials, including sand, common reed, reed canary grass and peatland biomasses, as bedding materials should be studied and advanced further.

Shives, by-products of the further processing of hemp fibres, can also be used as a bedding material. If domestic hemp fibre processing is scaled up, it is possible for domestic hemp-based bedding materials to be available. Currently, the use of hemp in bedding materials relies on imports. While oil hemp stems can also be used as a bedding material, their yield is not particularly high due to the harvesting methods used.

Bedding material cultivation could be one way to increase the production of bedding materials. Suitable crops for cultivation include reed canary grass and willow. An increase in paludiculture would enable the cultivation of bulrush as a bedding material. Reed canary grass is also suitable for paludiculture. However, promoting bedding material cultivation calls for incentives and effective markets.

Cooperation between farms is a widely used solution to secure the supply of bedding materials. Livestock and crop production farms could increase cooperation in bedding material production so that crop production farms cultivate bedding materials for livestock farms. Alternatively, livestock farms could harvest straw from crop production farms for use as a bedding, and correspondingly, cereal farms could receive straw back as manure. However, this needs incentives and good practical examples.

The availability of many bedding materials must be improved significantly if their use increases considerably. Then again, even if the availability of a certain potential material was high, its properties might require processing. This usually increases costs and may therefore limit the use of the material. Market surveys are also needed to produce the bedding materials required and find the correct target groups for them.

Options that are currently under development and testing may offer solutions for the supply of bedding materials in the future. More research and innovation, as well as courage from businesses to invest in bedding material production, are needed to produce new solutions. However, it should be noted that the development, production, and placement on the market of new bedding materials takes time – five to ten years in most cases. To make any investments in the production of bedding materials, we need incentives, including investment subsidies. The availability of current materials, especially that of peat, must be secured until proper options are genuinely available. This will ensure that livestock production and therefore the food industry do not need to be restricted due to any shortage of bedding materials.

Further research into bedding material supply is required especially regarding animal farming and welfare, various uses and working methods, the costs of bedding material production and handling, and the planning of the machine chains and processes required. It is important to identify the factors that determine how the supply of bedding materials matches their demand. It should also be understood that bedding material markets that operate at different levels may be needed more in the future. Some bedding material production may be very local, including cooperation between farms, while some may be regional, and some may be national.

Finding common guidelines and aiming to secure the supply of bedding materials now and in the future will be key, for which a comprehensive vision and effective interaction will be required. The various operators in the sector need to engage in even closer cooperation. If the current estimates are realised, the bedding material markets will undergo rapid change, and solutions will be required to adapt. We need not only to develop new bedding materials but also to improve the availability and resource-efficient use of wood- and peat-based bedding materials over a sufficiently long transition period to avoid the looming bedding material shortage. A roadmap to be prepared for bedding material supply by various operators in the sector is proposed as a solution so that it would define tangible short- and long-term plans to secure a sustainable supply of bedding materials.

Keywords: bedding material, bedding, peat, bedding material production, livestock pro-duction, horse husbandry, cattle, poultry, horse

Contents

1. Introduction

Currently, Finland's bedding material markets are experiencing major changes. Fiercer competition over raw materials suitable for use as bedding materials and the pressure to reduce the use of peat are key underlying factors. Concerns over the sufficiency of materials suitable for use as bedding materials and the general cost crisis have increased uncertainty of how to secure the supply of bedding materials in the future.

Because livestock production environments and farm buildings differ partly from those in other countries due to factors such as our climate conditions, not all foreign information can be applied to Finnish production. In addition, our good animal health situation, on which bedding has a partial impact, is something we do not want to compromise. Climate conditions also have a partial impact on the production of bedding materials, especially on materials used in crop production or harvested from nature. The assessment of bedding material supply must therefore address the Finnish operating environment.

Various materials are suitable for use as bedding materials, including peat, plant stems, wood-based materials, separated slurry or manure, peatland biomasses, sand, and paper. However, their properties may vary significantly, and they cannot be ranked in any specific order based on individual properties. Furthermore, there may be considerable differences in the availability, processing needs, used amounts and prices of various materials.

Regardless of the material, the key tasks of bedding materials include softening the bedding and keeping it dry, binding manure gases, acting as thermal insulation in cold conditions, and promoting the natural behaviour of animals. All these properties required from bedding materials have an impact on animal welfare and health, and partly on end-product quality and food safety. In addition, the opportunities offered by each bedding material and bedding practice for the circular economy must be considered. Bedding material supply also has an impact on the costs of livestock production and therefore on profitability.

Peat has long been one of the most commonly used bedding materials, especially because of its good bedding properties, high availability and competitive price. However, the pressure to reduce the use of peat for climate and environmental reasons has already had a negative impact on the availability and price of bedding peat. The resulting need to introduce new bedding materials to supplement and replace peat is accelerating quickly. At the same time, competition for them is becoming fiercer.

The suitability of peat and by-products of the forest and sawmill industries for various uses is a significant reason for the fiercer competition for bedding materials. As a result, their supply as bedding materials depends largely on competing uses. For example, sawdust and wood shavings obtained from sawmills have been increasingly targeted at energy generation during the last year, as there has been a shortage of materials suitable for heat production.

In livestock production, peat is especially critical in poultry production, as it is used as a bedding material on practically all broiler farms. Another challenge is that it is difficult to find a bedding material to replace the use of peat in broiler farming to secure the high foot health and antibiotic-free production of birds. Materials that replace and supplement peat are already available for cattle, horses, sheep, and pigs. However, their availability is a critical factor,

as certain materials are already in short supply. Furthermore, not all materials may be usable in every livestock production and farming environment.

In securing the supply of bedding materials, the costs arising from it must also be addressed. In the worst case, an increase in bedding costs may cause farmers to compromise on bedding, which is unreasonable considering sustainable, ethical, or profitable production. The profitability of production must be ensured if production costs increase, as this is a requirement for domestic food production.

Ensuring the sufficient availability of bedding materials and the effectiveness of bedding in every situation, considering the resulting costs and environmental impact, is a key element of securing the supply of bedding materials. The primary purpose of this report on bedding materials was to investigate the use and availability of different bedding materials as comprehensively as possible and assess certain future outlook and development needs related to them.

2. Data collection and limitations

Data collection started from the current state of livestock production and the use and availability of bedding materials. In addition, the future development outlook of the bedding material markets and especially bedding peat was assessed. For bedding peat, the estimate of the development of production amounts extends to five years from now. The aim was also to address any changes in livestock production, especially quantities, when assessing the development outlook related to demand for bedding materials.

Data collection was based on literature, official statistics, expert assessments, and the surveys conducted during the study. Two surveys were conducted, one targeted at livestock producers and horse sector operators, and the other at producers, sellers and/or distributors of bedding materials.

To examine the regional production and use of bedding materials, Finland was divided into four major regions: Southern, Western, Middle and Northern Finland (Lehtonen 2015). The major regions addressed the areas of the Centres for Economic Development, Transport and the Environment (ELY) so that the ELY Centre areas remained unbroken within each major region (Figure 1).

Figure 1. Division into major regions in accordance with the ELY Centre areas.

Lacking comprehensive information about the use and amounts of the various available materials so as to address different bedding materials and their use with different animals and in different production environments particularly complicated the evaluation of the amounts of bedding materials used. Another challenge was that bedding materials can also be used in mixtures, and a single farm may use several materials at the same or at different times. In addition, the amounts of bedding materials used with different animals show significant variation, which makes it more difficult to evaluate average amounts. The properties of bedding materials may vary considerably, even when examining a single material, which may affect the amounts used.

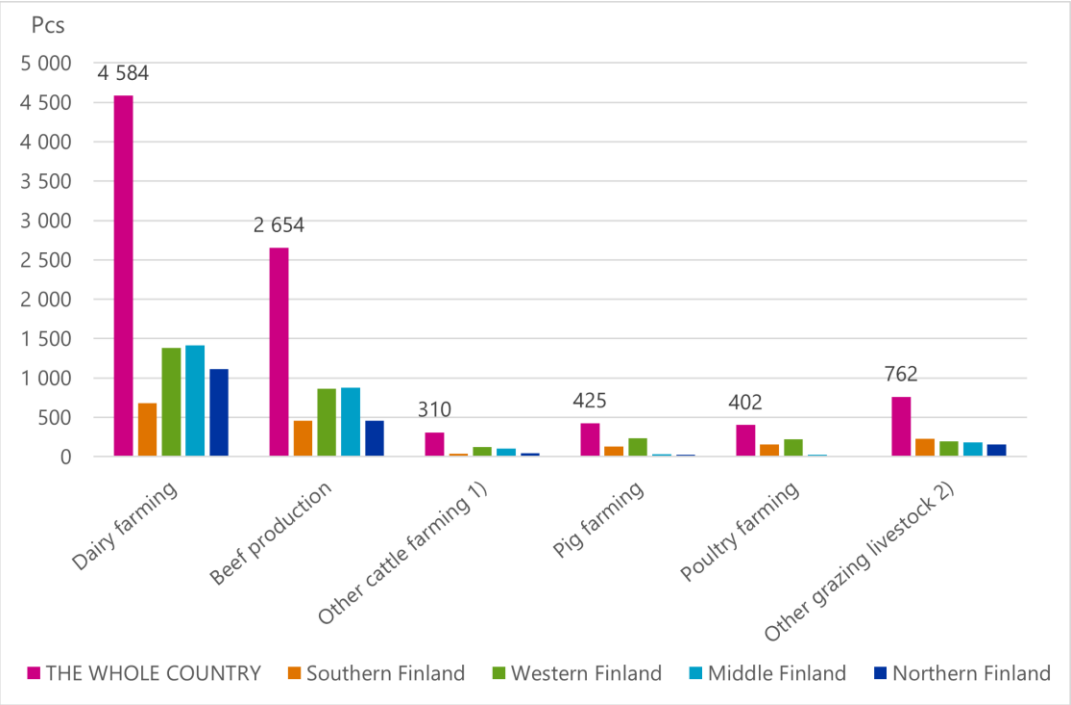
It was impossible to reach commercial operators in the bedding material sector and end users of bedding materials extensively to obtain comprehensive information. Access to information was also partly limited by competitive factors. Not all operators were willing to disclose information about their volumes and prices. The requirements set by competition law also meant that any information that may affect the markets cannot be presented. Furthermore, not all the information obtained could be published for reasons of confidentiality due to the low number of operators. Considering end users, evaluating the amounts of bedding materials used presented a particular challenge. When evaluating the amounts of imported bedding materials, the difficulty was that no customs statistics for them were available for a closer examination of imported amounts. The data collected for this report are therefore partly based on indicative information.

3. Livestock farms and the number of animals, and their development in the near future

3.1. The number and regional distribution of livestock farms and stables

The number of livestock farms and their distribution by major region are presented in Figure 2. The grouping of farms according to main productions is based on the standard output (SO) method, in which the main production is determined based on a company's financially most significant main production. If more than two thirds of a farm's total income come from a single product, the farm will be assigned to the main production matching the product; otherwise, it will be determined as a mixed farm (Official Statistics of Finland (OSF): Structure of agricultural and horticultural enterprises).

In 2022, the number of farms with livestock farming as their main production totalled 9,137 in the whole country (Figure 2). The majority, or 83%, were cattle farms. Poultry farms accounted for 4%, pig farms for 5%, and sheep and goat farms for 8%. Of dairy cow farms, slightly fewer than two thirds (61%) were located in Middle Finland and Western Finland, and almost a quarter (24%) in Northern Finland. In addition, most beef production farms (66%) were located in the regions of Middle Finland and Western Finland. Pig and poultry farms were mainly in Western Finland, which was home to more than half of all such farms (55%). Slightly less than a third of pig farms (31%) and slightly more than a third of poultry farms (39%) were in Southern Finland. Sheep and goat farms (other grazing livestock) were fairly evenly distributed between different regions, with variation between regions ranging from 21% to 30%.



[1] Combined dairy farming and beef production. [2] Sheep and goat farming.

Figure 2. The number of livestock farms by main production and major region in 2022. If more than two thirds of a farm's total income comes from a specific product, the farm's main production matches the product in question. Source: Official statistics of Finland (OSF): Structure of agricultural and horticultural enterprises.

Horse keeping sites are mainly located outside farms. Currently, there are some 10,000 horse keeping sites, or stables, in the Finnish Food Authority's keeping site register (Figure 3). Based on support paid to farms for horses (CAP, LFA, national support) roughly 2,500 farms have horses, accounting for almost a third of all horses (fewer than 20,000 horses of different ages). Horse stables were mainly located in the regions of Southern, Middle and Western Finland, each of which was home to roughly a third of all stables (Figure 3).

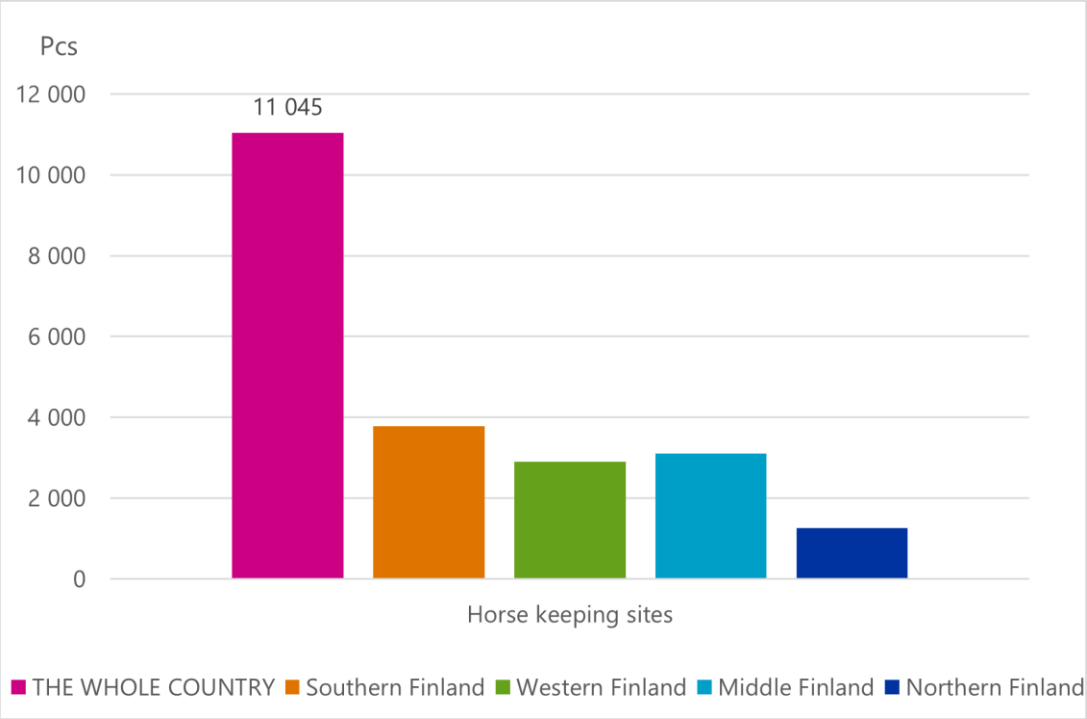


Figure 3. The number of horse keeping sites in the whole country and by major region in 2022. The figures are based on the Finnish Food Authority's animal owner and keeping site register.

Stable units are usually small. Based on the Finnish Food Authority's animal owner and keeping sites register, a single keeping sites has an average of 6.5 places for horses. According to the register, some 2% of all stables included stable units for more than 30 horses, while harness racing and riding centres may have up to 50–150 horses in various stables. While each of these is regarded as a separate keeping sites, they may be covered by joint bedding material and manure maintenance. Incorporated stables consist of an average of 14.5 places for horses, or more than double that of the average of all keeping sites (Saastamoinen 2018).

3.2. The number and regional distribution of livestock and horses

At the beginning of 2022, cattle numbered roughly 822,000 (Figure 4). Dairy cows accounted for 30%, bulls for 12% and suckler cows for 8%. Others were heifers and calves less than a year old. In the major regions, the number of cattle was highest in Western Finland (35%), and the lowest in Southern Finland (16%).

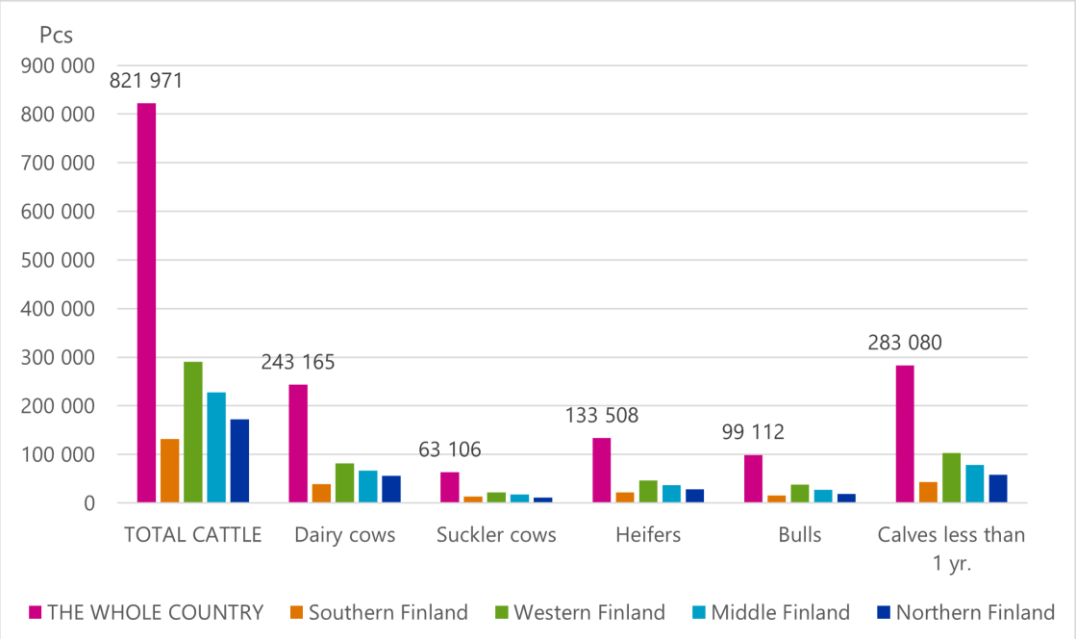
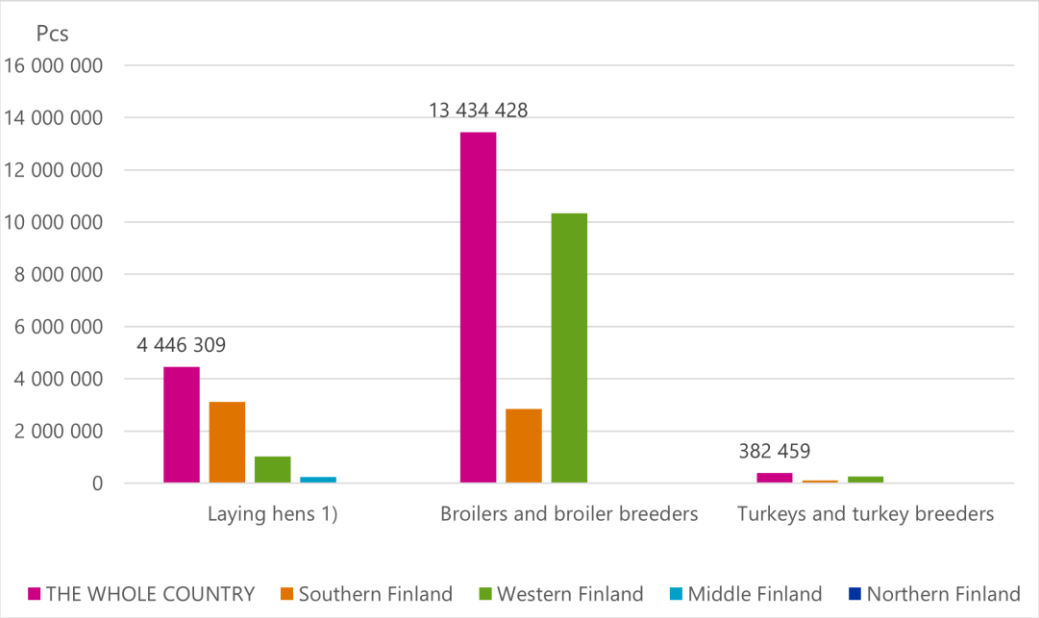


Figure 4. The number of cattle in the whole country and by major region on 1 December 2022. Source: OSFa: Number of livestock.

The number of laying hens, broilers, and turkeys at the beginning of April 2022 is presented in Figure 5. At the time, growing broilers and broiler breeders numbered some 13.4 million (Figure 5), and laying hens (including those of more than 16 weeks of age and breeding hens) totalled roughly 4.4 million. The number of turkeys and turkey breeders was some 382,000. In particular, when examining the number of meat poultry, it should be noted that the number of annually produced birds is many times higher than the number recorded in statistics, as statistics present the situation at a specific time, whereas several batches of birds are produced per year. For example, broilers are produced in an average of seven batches per year. Broiler and turkey production mainly took place in Western Finland, while egg production was focused on Southern Finland.



[1)] Including productive poultry and breeding hens.

Figure 5. The average number of poultry in the whole country and by major region on 1 April 2022. Source: OSFb: Number of livestock.

The number of pigs in the whole country at the beginning of April 2022 was roughly 1.06 million (Figure 6). Pork production was concentrated in the major regions of Western and Southern Finland. The number of pigs was highest in Western Finland. Similarly, to the number of poultry, it should be noted that the number of animals is recorded in statistics at a specific time of the year. During each year, three to four batches of fattening pigs are produced, and each sow farrows twice, which affects the total number of fattening pigs and piglets per year.

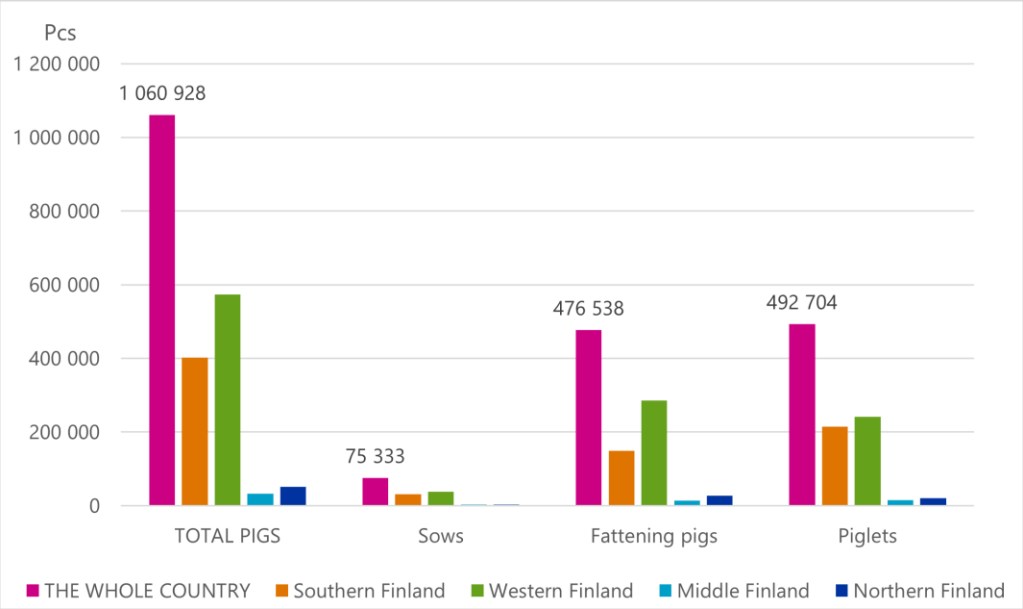


Figure 6. The number of pigs in the whole country and by major region on 1 April 2022. Source: OSFc: Number of livestock.

According to the data of the Finnish Food Authority and the central organisation for trotting and horse breeding (Suomen Hippos), the number of horses was estimated at 72,000 in 2023 (Figure 7). Regionally, horses were distributed fairly evenly in the major regions of Southern, Western and Middle Finland. The number of horses was lowest in Northern Finland.

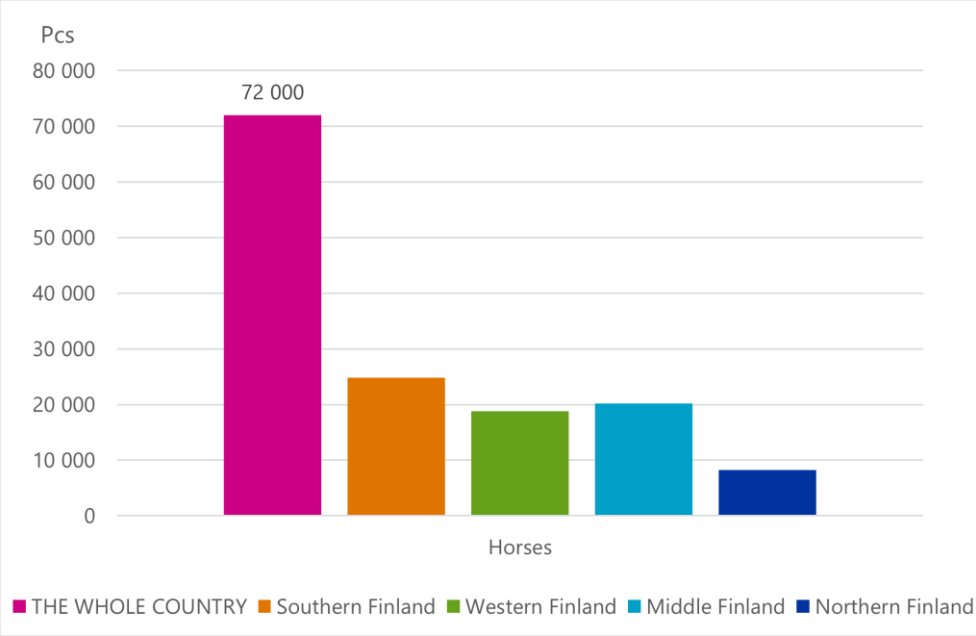


Figure 7. The number of horses in the whole country and by major region in 2023. The number has been estimated based on the data of the Finnish Food Authority and Suomen Hippos.

3.3. Future development outlook for livestock production

The future development outlook for livestock production is based on Kantar's 2022 development outlook survey for producers. It is also based on certain results obtained from Kantar's 2023 survey, which was more limited than usual, only covering dairy cattle, beef cattle and pig farms.

Based on the results of the 2022 survey, the number of milk farms will decrease to fewer than 4,000 farms in roughly two years and close to 3,000 farms by 2027. During this period, the annual milk farm discontinuation rate would be 7.4% on average if this estimate were realised. By 2030, the number of milk farms would be slightly more than 2,300. According to the estimate, most smaller farms will discontinue milk production during the next few years.

The number of suckler cow and other cattle farms is also expected to decrease in the near future. In 2027, the number of suckler cow farms would be roughly 1,450, and that of other cattle farms approximately 950. The annual discontinuation rate would be 6% for suckler cow farms and 8.4% in other specialised beef production. By 2030, the number of suckler cow farms would be 1,220, and that of other cattle farms 780.

The number of dairy cows is expected to decrease by roughly 13,000 during the next two years and by almost 30,000 by 2027, when the total number will be less than 220,000. According to the most likely scenario defined in the newer development outlook survey conducted in 2023, there will be 202,000 dairy cows in 2030. The number of cows is expected to fall most dramatically between 2022 and 2027 in the regions of Northern Savonia, Southern Ostrobothnia and Northern Ostrobothnia.

Based on the estimate prepared using the 2022 results, the number of suckler cows will be roughly 62,000 in 2027 and 59,000 in 2030, provided that no uncertain investments are made. According to the most likely scenario defined in the newer survey conducted in 2023, there will be 56,000 suckler cows in 2030. The number of animals is also expected to fall in beef production, as the number is based on the number of dairy and suckler cows, both of which will decrease in the near future. Based on the 2022 survey, the number of growing and finishing capacity for slaughter may decrease by 90,000 during the next five years through discontinued operations.

According to the estimate, almost half of all chicken farms will discontinue their production by 2030. However, the average size of henhouses will increase during the next few years. The number of poultry meat farms is also expected to decrease slightly in the near future. According to the Finnish poultry association, no significant changes are expected in the next few years in broiler production.

Based on the 2022 development outlook survey, the number of pig farms is expected to decrease. According to the estimate, there would be 450 farms in operation in 2027 and 330 in 2030. The number of sows is expected to be 69,000 in 2027 and 67,000 in 2030. Based on the 2023 development outlook survey, there are expected to be 65,000 sows in 2030. The development of piglet production determines how many fattening pigs and weaned piglets are in production at each time. Based on the 2022 survey, producers' expectations of an increase in piglet production, which is estimated at 0.3 piglets per sow per year, compensates for the decrease in production.

Equine sector is susceptible to economic trends, with any increase in the number of horses usually stopping in a weaker economic situation, as is also the case during the current trend. Near-future development therefore depends on upcoming trends, and it seems that the number of horses will remain fairly unchanged during the next few years. If the economic situation improves, the number of horses will increase with a slight delay, as rearing (the number of foals) reacts slowly, which partly prevents or at least decelerates any future increase in the number of horses. According to the current estimate, there will be no significant changes in the number of horses in the near future.

4. Significance of bedding in animal farming

4.1. Bedding is part of animal welfare and food hygiene

Bedding is a key factor affecting animal welfare and health. In addition, effective bedding and animal cleanliness secure the hygienic quality of foodstuffs.

Regardless of the material used, key tasks of bedding materials include softening the bedding, keeping it and animal dry, binding gases discharged from urine and manure, and acting as thermal insulation in cold conditions. Effective bedding facilitates animal cleaning, makes the work required for bedding easier, and improves air quality in production buildings, which has an impact on the health and welfare of animals and people alike. Different animal species have different bedding methods.

Manure is a significant risk factor for food hygiene, as it may be transferred from dirty animals to end products. It is therefore important to ensure the cleanliness of animals and end products. For animal health and food hygiene, it is essential to keep animal facilities clean and dry, as microbes thrive in wet and manure-rich areas. Effective bedding keeps the animal area dry, making life difficult for microbes.

A properly bedded area is soft and comfortable for animals. However, not all bedding materials are suitable for all animal species, as they prioritise certain bedding materials according to their behavioural needs. For example, comfort is one of the most significant welfare factors for cattle and horses, and they prefer effectively bedded mattresses (Mills et al. 2000, Tucker & Weary 2004). Soft bedding also reduces and prevents skin damage. In addition, any faeces adhering to animals damages the skin of animals. Undamaged skin protects animals, preventing harmful microbes accessing any tissue underneath the skin. Furthermore, clean hairs and feathers also protect the skin and act as thermal insulation in cold conditions.

The regular and sufficient use of bedding materials is a requirement for effective bedding. It is therefore important to ensure the sufficiency of bedding materials. When selecting bedding materials, their bedding properties and suitability for the intended situation and conditions must be addressed.

4.2. Bedding is a farm-specific solution

The selection of bedding materials is always a comprehensive farm-specific solution, which is affected by the properties required of bedding materials in different situations. In addition, various other factors must be addressed, including availability, the amounts used, usability and price. Any need of processing, the suitability of the bedding equipment used, and the storage space required also have an impact on the selection. The amount of manure generated and the opportunities for further use should also be taken into account.

Bedding materials can be used exclusively as bedding materials or as various mixtures. When used as mixtures, the amount of individual bedding materials is lower. In addition, different materials can supplement one another. When used as mixtures, it is also possible to use such materials that may not necessarily be usable exclusively as bedding materials. The amount of bedding materials used also affects their properties. For successful bedding, it is important

that the number of animals is dimensioned correctly according to the conditions and the available amount of bedding materials. If the animal density is too high, and the area is not bedded sufficiently, animals will quickly become dirty.

When comparing bedding materials, they cannot be ranked in any specific order because they have different properties. Furthermore, the effectiveness of materials as a bedding material or their amounts cannot be assessed based on individual properties alone, as each bedding material needs to be considered as a whole based on several properties required from bedding materials. It should also be understood that the properties of materials may change from one production batch to the next. After all, the selection of bedding materials is always a comprehensive farm-specific solution, which is affected by the properties required of bedding materials in different situations.

The amounts of bedding materials used can be measured by volume or weight. Similarly, pricing can be based on volume or weight. The weight by volume depends especially on the moisture of the material and the density of its packaging.

4.3. Legislation on bedding materials

The literature review by Palva and Alasuutari (2014) stated that there were no straightforward regulations or quality requirements for bedding materials. However, expert interviews indicated a connection to regulations on veterinary medicine, food hygiene and feed. These are presented in the following paragraph.

Considering legislation on veterinary medicine, it must be ensured in the manufacturing process for bedding materials that no infectious animal diseases can spread through bedding materials. Regarding food hygiene regulations, bedding materials cannot present any food hygiene risk. Legislation on feed defines that manure, urine or the content of the gastrointestinal tract cannot be used as feed. In this context, this is mainly connected to the use of manure-based bedding materials. In this case, it should be noted that animals may eat bedding materials. Even though feed legislation cannot be directly applied to the use of manure-based bedding materials, the safety of bedding materials must always be ensured.

According to the guidelines presented on the Finnish Food Authority's website (2022) regarding the use and handling of manure, records of any manure delivered outside a farm must be maintained, indicating the amount of the manure delivered and the delivery date. This is significant for bedding materials if dry components separated from slurry or dry manure are used as a bedding material, and the slurry or dry manure is processed outside the farm.

Considering bedding materials, it should also be noted that in many forms of animal production, bedding materials end up in fields through manure or slurry, in which case bedding materials cannot contain any harmful substances that cannot be spread on fields. If manure is delivered for further processing to make any products placed on the market, the maximum concentrations set for harmful substances in fertiliser products made and marketed in accordance with the national fertiliser legislation must be addressed. These are indicated on the Finnish Food Authority's website (Finnish Food Authority 2023).

5. Peat as a bedding material

5.1. Properties of bedding peat

Peat is a bedding material used extensively in Finland. The largest quantities of bedding peat are used for horses, cattle and broilers. The popularity of peat as a bedding material is especially based on its many good properties that have an impact on animals and the conditions of the animal area.

Peat has an excellent ability to bind moisture and gases discharged from urine and manure, especially ammonia, and therefore reduces odours in the animal facilities. Acidity (pH 3.5–5) is one of the advantages of peat, ensuring that it is not an optimal culture medium for pathogens. Peat's good capacity to bind ammonia is also based on its acidity. In addition, peat has (antiseptic) properties that prevent the growth of harmful microbes which is significant considering animal health. Peat is a porous material which makes it a soft bedding material. It also acts as enrichment, improving the natural behaviour of pigs and poultry in particular. Pigs can easily dig into peat, while it offers an excellent scratching and bathing material for poultry.

When using bedding peat, broilers typically have high foot health (Kaukonen et al. 2017), and horses have better respiratory health than when other bedding materials are used (Saastamoinen et al. 2015, Mönki et al. 2021). The use of peat as a bedding material for broilers has helped enable antibiotic-free broiler production.

Peat has good properties for use. It is suitable for use as a bedding material for production animals and horses, and it can be used in very different production environments and systems. Its ease of use is another advantage, as peat can be used as such without requiring any further processing before bedding. In addition, peat manure offers good opportunities for further use, which is particularly important in horse sector, in which manure usually has no uses. On farms that generate high amounts of manure, it is also important that it can be used as a fertiliser, for example.

The disadvantages of peat include its dust generation and its light weight in certain situations. As a very light material, peat stays poorly in stalls. Changes in quality, especially regarding the dry matter content and the degree of decomposition, may cause problems. Problems with peat that is too wet and decomposed include its low ability to bind water and freezing in cold conditions. In addition, uneven quality, including pieces of wood in peat, may cause problems in bedding equipment, for example. The dark colour of peat is often regarded as a negative factor.

5.2. Use of bedding peat for broilers

The significance of peat as a bedding material is particularly emphasised on poultry farms, as 90% of poultry farms use peat as a bedding material. In broiler chicken houses, it is recommended that a 2 cm layer of bedding peat be used (Hamina 2023). There is an average of 17 broilers per square metre, with the number ranging from 15 to 18 individuals in practice. In broiler chicken houses, the production of a single batch takes an average of 35 days, and there is a break of roughly two weeks between batches. There is an average of seven production batches per year. In Finland, the average size of a broiler farm is roughly 75,000 broilers (Finnish poultry association).

Based on the information above, a single broiler farm consumes some 576 m^3 of bedding peat per year. Broilers are produced on approximately 170 farms (Finnish poultry association). Accordingly, some 98,000 m^3 of bedding peat is used in broiler production per year. When other poultry production is included, the total amount of bedding peat used annually in the whole poultry sector is roughly 120,000 m^3 (Hamina 2023).

5.3. Use of bedding peat for horses

Peat is the most commonly used bedding material in horse sector because of its good drying and further use properties. According to studies, peat accounts for an average of 42–46% of all bedding materials used for horses (Iivonen 2008, Luostarinen et al. 2017, Aro et al. 2021), totalling 370,000–400,000 m^3 of peat per year. Per horse, some 10–12 m^3 of peat is used per year, while the amount may be up to 20 m^3 in different studies and reports.

For horses, peat is preferred based on its advantages and positive impact, proven in studies and in practice, regarding horse health and welfare, including respiratory health (Saastamoinen et al. 2015, Bambi et al. 2018, Mönki et al. 2021). High-quality indoor air maintained by peat-based bedding also has an impact on workers' health.

The dark colour of peat and the "scruffy" impression it makes compared to lighter bedding materials reduce the popularity of peat as a bedding material. Peat is therefore used in some amounts pre-mixed or mixed on farms with wood-based bedding materials.

Because only some horse stables and less than a third of horses are located on farms, horse manure is used in agricultural and horticultural production or in making soil and growing medium products based on agreements. For this purpose, peat-containing manure is considered the most suitable and desirable, which makes it easier to dispose of horse manure. The use of wood-based manure on fields is not preferred because it is considered to reduce harvest levels, as disintegration consumes nitrogen or has a negative impact on the warming of the soil.

5.4. Use of bedding peat for cattle

The amounts of peat used on cattle farms may vary significantly, depending on production buildings and manure removal systems. In uninsulated production buildings and deep beddings the amounts are many times higher compared to insulated buildings and stalls

The percentage of peat of all bedding materials used shows significant variation on cattle farms, ranging from 6% to 44% (Iivonen 2008). Peat is a more commonly used bedding material on beef cattle farms than on dairy cattle farms. It is estimated that peat accounts for 29–44% of all bedding materials on beef cattle farms and 6–24% on dairy cattle farms (Iivonen 2008). No up-to-date information is available about the average amounts of bedding peat used in milk and beef production. However, the amount of peat used in bedding for cattle can be estimated by deducting the amount used as a bedding material for poultry (120,000 m^3) and horses (370,000–400,000 m^3) from the total annual amount of bedding peat (1,320,000 m^3, see Table 1). The majority of the remaining amount – 800,000–830,000 m^3 – is used as a bedding material for cattle.

According to Kantar's 2023 development outlook survey, larger suckler cow and slaughter production farms used peat more than smaller farms. According to the survey, straw was the most commonly used bedding material on beef cattle farms, while the percentage of peat increased with larger farm sizes. A total of 29% of farms specialising in slaughter production used peat.

6. Production, availability and near-future development outlook of bedding peat

Table 1 summarises the current supply volumes of bedding peat and the amounts extracted for own consumption. The amounts are presented at the level of the whole country and divided into the major regions. In addition, Table 1 presents an estimate of the availability of bedding peat during the next five-year period. Figure 8 describes the current supply volumes of bedding peat and an estimated amount during the next five-year period at the level of the whole country and divided into the major regions. The amounts include bedding peat placed on the market and peat extracted for own consumption. The regional amounts represent the bedding peat amount delivered in each region, not the amount extracted there.

Table 1. Current supply volumes of peat and amounts extracted for own consumption and a five-year estimate.

	Total volume	**Western Finland**	**Southern Finland**	**Middle Finland**	**Northern Finland**
Current situation, m^3/year					
Supply	1 240 000	520 000	370 000	210 000	140 000
Extracted for own consumption[1)]	80 000	60 000	10 000	5 000	5 000
Total	**1 320 000**	**580 000**	**380 000**	**215 000**	**145 000**
Forecast for five years ahead, m^3/year					
Supply	633 621	276 773	232 819	84 304	39 726
Extracted for own consumption	80 000	60 000	10 000	5 000	5 000
Total	**713 621**	**336 773**	**242 819**	**89 304**	**44 726**
Decrease, %					
In supply volume	**49**	**47**	**37**	**60**	**72**
Of the total volume	**46**	**42**	**36**	**58**	**69**

[1)] Excluding peat placed on the market. Calculation based on roughly 80 sites of 5 hectares each, with a total area of 400 hectares.

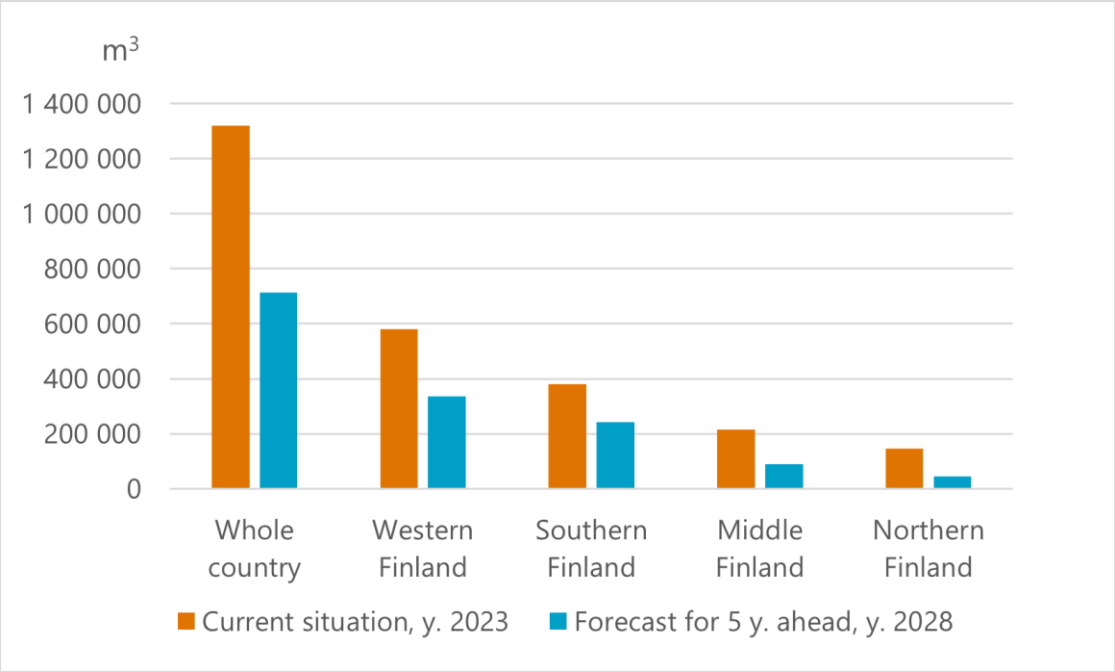


Figure 8. The current amounts of bedding peat and the five-year development outlook in the whole country and by major region. The figures include supply of bedding peat and extraction for own consumption.

The available amount of bedding peat is expected to decrease by 46% from the current total amount during the next five years. This means that the amount will almost halve from the current level. In practice, this means that less bedding peat will be placed on the market, as the extraction of bedding peat for own consumption is expected to remain unchanged or even increase slightly, provided that the bedding peat placed on the market is insufficient to meet demand.

When examined by region over a five-year span, the total amount of bedding peat is estimated to decrease by 36–39%. Measured by percentage, the decrease will be most significant in Northern Finland, in which supply volumes and extraction amounts for own consumption are already the lowest, and least significant in Southern Finland. Measured by amount, the decrease will be most significant in Western Finland, in which supply volumes and extraction amounts for own consumption are also highest.

The average annual decrease in bedding peat calculated from the total amount is estimated at 9%, while there may be considerable annual and regional variation. Quantitatively, this translates to an average annual decrease of approximately 121,000 m^3.

Currently, there are practically no bedding peat stocks remaining from the previous years. In practice, the amount extracted each summer is sold before the following extraction period. This is a particularly critical situation if the summer is rainy, which reduces the extraction of peat and causes production to fall short of the average level. As a result, bedding peat will be in even shorter supply.

One of the advantages of bedding peat is that it can be stored in clamps in peatlands under plastic so that no separate storage buildings are needed. Peat remains usable for 2–3 years when stored under plastic. From the production and storage location, it can be transported directly to where it is used. This affects storage and transport costs. Furthermore, if peat is

stored in higher amounts than is needed during the year, the security of bedding material supply will increase.

In addition, fuel peat has no alternative uses as a bedding material. Its properties do not allow its use as a bedding material because it is mainly fine-grained and decomposed peat, unlike light low- or medium-decomposed sphagnum peat, which is suitable for use as a bedding material. Currently, peat is only produced for heat production according to demand. This means that there are no extra stocks. As a result, even if the use of peat for heat production decreased significantly, this would not improve the bedding material situation.

The peat working group's final report stated that the extraction of the surface layer alone in Finnish peatlands was financially unprofitable (Korhonen et al. 2021) because the profitability of peatlands was based on sales of energy peat. If only the surface layer was extracted, the production costs of light peat would double (Korhonen et al. 2021).

7. Field biomasses and other plant stems as bedding materials

Field biomasses cover materials that are obtained from fields in addition to the production of main crops or produced in bedding material cultivation, and that are suitable for use as bedding materials. Bedding materials obtained in addition to the production of main crops mainly include the straw of cereals and other crops, as well as shives, meaning the inner parts of hemp. Plants suitable for bedding material cultivation include reed canary grass and bulrush, which also grow in nature. Other plant stems include natural common reed.

Plant stems can be used as bedding materials as such, shredded or pelleted. Shredding can improve the water binding capacity of the material when the absorption area increases, and the inner part not protected by wax becomes visible. Plant stems as such or shredded are most suitable for bedding in certain deep bedding areas and pens. Non-shredded plant stems are not usually suitable for use in slurry systems.

Plant stems can also be grinded and then pelleted, in which case the material's weight by volume increases considerably compared to the raw material used. At the same time, its absorption ability usually improves. In addition, pelleting often makes the material easier to handle and reduces the generation of dust. When wet, pellets expand into a soft and absorptive material. Pellets are usually packaged in bulk bags (typically 1000 l).

7.1. Straw as a bedding material

Straw is the most common stem material used as a bedding material. Regardless of the harvesting and storage method, it is important to ensure that no mould accumulates in the straw intended for use as a bedding material during storage, as it may present a significant health risk for animals and workers. Wet straw offers an effective culture medium for mould and other microbes.

When straw is stored dry, the moisture content cannot be more than 20% to ensure good storage results (Bernesson & Nilsson 2005). To maximise preservability and minimise loss, dry straw should preferably be stored in dry conditions under a cover or plastic. However, it should be noted that when stored under plastic in field conditions, straw absorbs moisture from below, which reduces its preservability.

If straw needs to be harvested with a higher moisture content than recommended due to wet harvesting conditions, straw bales must be wrapped in plastic to ensure their preservability (Lötjönen & Joutsjoki 2016). Based on the study by Lötjönen and Joutsjoki (2016), three layers of plastic are sufficient for winter storage, but if straw is stored for a year, six layers are recommended. The downside of wrapping is that it increases the amount of work and costs and generates plastic waste. One option is to harvest straw using a shredder and store it as bulk material (Manni & Huuskonen 2021a).

Alongside peat, straw is a commonly used bedding material especially in uninsulated production buildings for beef cattle and in bedding for horses. However, any awns in straw used for horses may cause problems, which is why only oat and wheat straw is used for them. General advantages of straw include its high thermal insulation capacity, which is particularly significant in cold conditions.

7.2. Calculated production potential of straw

The calculated production potential of straw was calculated for key cereal crops (barley (*Hordeum vulgare*), oats (*Avena sativa*), wheat (*Triticum aestivum*), rye (*Secale cereale*)) using the formula developed to evaluate by-product biomass: (1 - harvest index) × dry harvest weight ÷ harvest index (Hakala et al. 2009). According to Hakala et al. (2009), 30% was deducted from the calculated figure, as it represented the average biomass remaining in stubble. Crop-specific harvest indices were used (Hakala et al. 2016). The calculation was made using average yields calculated for 2012–2022 and the period's minimum and maximum yields (OSF: Crop production statistics). Each cereal crop's average cultivation area calculated for 2012–2022 was used as the harvesting area (OSF: Crop production statistics). Calculated using the period's average yields, the total annual amount of straw was roughly 2.4 billion kg. The total amount was 1.7 billion kg when calculated using minimum yields and 2.8 billion kg when using maximum yields. All crops produced maximum yields in 2019, whereas minimum yields took place in different years (in 2021, for barley and oats; in 2018, for wheat; and in 2013, for rye). Table 2 presents the average yields of straw per cereal species and per hectare, as well as the production potential calculated for the entire cultivation area using average yields in 2012–2022 and the same period's minimum and maximum yields.

Table 2. The calculated annual production potential of straw for key cereal crops based on average yields calculated for 2012–2022 and the same period's minimum and maximum yields. The average cultivation area in 2012–2022 has been used. The harvest data and cultivation areas are based on Luke's statistics (OSF: Crop production statistics).

	Harvest area, ha	Straw, kg/ha			Total straw, kg		
		At average yield	At minimum yield	At maximum yield	At average yield	At minimum yield	At maximum yield
Barley	423 000	2 071	1 523	2 423	875 736 825	644 144 281	1 024 334 702
Oats	307 000	2 390	1 757	2 751	732 504 298	538 600 364	843 306 545
Wheat	217 000	3 235	2 378	3 901	701 182 194	515 560 267	845 667 200
Rye	23 000	3 539	2 195	5 061	81 568 339	50 573 250	116 633 045
Total	969 000				2 390 991 655	1 748 878 161	2 829 941 493

Table 3 summarises the cultivation areas of key cereal crops (barley, oats, wheat, rye) in the whole country and by major region in 2022. Examined by major region, those of Southern and Western Finland account for 82% of the whole country's total cultivation area, also constituting the most significant straw production regions when measured by amount.

Table 3. Cultivation areas of key cereal crops (barley, oats, wheat, rye) in the whole country and by major region in 2022. Source: OSF: Utilised agricultural area.

	Whole country	Southern Finland	Western Finland	Middle Finland	Northern Finland
Area of main cereal crops, ha	1 015 000	445 000	387 000	96 000	87 000
Share of the area under main cereal crops, %		44	38	9	9

However, only part of the calculated straw yield is used as a bedding material. The straw yield used as a bedding material depends particularly on weather conditions during the growing season and their impact on the crop harvest level and straw harvesting conditions. Straw harvesting becomes more difficult when the weather is wet and unsettled, in which case the moisture content in straw may be up to 60% during harvesting. Other factors affecting the use of straw as a bedding material include the location of fields relative to livestock farms that use bedding materials and other uses of straw.

Crop production farms require straw to preserve organic matter in fields and maintain the soil structure. Therefore, harvesting straw from fields used for crop production may not necessarily be a sustainable long-term solution unless straw is returned to the field in the form of manure, for example. Considering the carbon content and vitality of soil, straw should be left unharvested in each parcel every other year (Hakala et al. 2016). This is particularly important in situations where no manure is spread on fields.

The location and harvest levels of fields have an impact on the use of straw as a bedding material. The farther a field is from a farm that uses straw as a bedding material, the higher the costs will be, at least regarding transport. In addition, the lower the harvest level is, and the shorter the stem is, the less straw can be obtained per hectare, and the higher the harvesting area and costs will be.

Although straw is a well-known and extensively and widely used bedding material, the value and potential of domestic straw as a bedding material may yet to be fully understood. The use of straw could be increased in cooperation between farms and in large-scale commercial activities. However, this requires current harvesting, further processing, storage and transport methods to be developed cost-effectively. Increasing the use of straw in bedding materials would lead to larger harvesting areas and longer transport distances than at present. However, longer transport distances may be a reality in the future.

Examples of domestic products on a commercial scale include straw pellets, which are commonly used on horse farms in particular. Currently, nearly all straw pellets used in Finland are of foreign origin. They are imported especially from the Baltic countries and in smaller amounts from Central Europe. Fiercer competition for materials used in energy generation is currently reflected in the availability and price of straw pellets. Their availability has decreased, and they are also in short supply in places, and no relief is in sight, at least in the short term. The price of straw pellets has also increased. There could therefore be potential markets for their domestic production.

7.3. Reed canary grass

7.3.1. Reed canary grass as a bedding material

Of field biomasses, reed canary grass (*Phalaris arundinacea*) is one of the crops with most potential for use in bedding material cultivation. It is a perennial grass crop that survives the winter, produces high yields and has a long life. Typical dry matter yields are 3–7 tonnes per hectare (Lötjönen & Knuuttila 2009). In productive areas, the dry matter yield is roughly 6–8 tonnes per hectare from the second harvest year when harvested in the spring, and the ability to produce yields can remain high for up to 10–12 years (Pahkala et al. 2005, Lötjönen & Knuuttila 2009). Reed canary grass grows naturally by waterbodies, and it can be grown in all

types of soil. Clay- and peat-containing soils are the most ideal for its cultivation, usually producing the highest yields (Pahkala et al. 2005). In addition, peatlands from which peat is no longer extracted seem suitable for reed canary grass cultivation (Pahkala et al. 2005). Reed canary grass resists moisture well, which is why it is also suitable for paludiculture.

When starting reed canary grass production, it should be noted that the crop grows its roots for the first couple of years, and the first yields are only produced two years after sowing (Lötjönen & Knuuttila 2009). Reed canary grass does not require any intense fertilisation. During harvest years, the recommended amount of nitrogen fertilisation is 60–90 kg per hectare, depending on the type of soil and clay content (Pahkala et al. 2005). Reed canary grass can be harvested using regular grassland harvesting machinery. Harvesting can take place in the spring immediately after the field has a sufficient load-carrying capacity or late in the summer.

The history of reed canary grass cultivation is based on its use as energy, although it is currently produced for use as a bedding material and in growing media. Shredded reed canary grass and pellets are already produced on a commercial scale in Finland, in addition to which reed canary grass pellets are imported from the Baltic countries, among others. Pellets are mainly sold as packaged and branded product names.

Reed canary grass is suitable for use as a bedding material for cattle and horses (Manni & Huuskonen 2021b, Tuomisto et al. 2021, Manni et al. 2022, Saastamoinen et al. 2022). It can be used both when shredded and pelleted. However, it is difficult to compare shredded and pelleted products due to the fairly low amounts of reed canary grass used and insufficient research data. The use of reed canary grass as a bedding material is limited above all by its low availability and price.

Reed canary grass binds liquids and odours well and produces heat (Manni & Huuskonen 2021b, Manni et al. 2022, Saastamoinen et al. 2022). It has also provided good user experiences. The most significant disadvantage of reed canary grass is the large amount of dust generated. However, it can be reduced through pelleting. Pellets are mainly used for horses. When using reed canary grass as a bedding material for horses, it should be noted that horses do not typically eat reed canary grass pellets, unlike straw pellets.

In reed canary grass trials, shredded reed canary grass was unsuitable for use as a bedding material for broilers (Da Silva Viana et al. 2022). In the trials, birds' feathers were dirtier than when using sphagnum moss or peat, in which case bird feathers were only slightly dirty. In addition, when using shredded reed canary grass, significant damage was identified at the bottom of birds' feet, unlike when using sphagnum moss or peat, in which case practically no damage was found (Da Silva Viana et al. 2022). In the most recent studies, shredding reed canary grass into smaller pieces and mixing them with sphagnum moss considerably improved the suitability of reed canary grass for use as a bedding material for broilers (No-Zoon project, Luke, unpublished results).

7.3.2. Production potential of reed canary grass

One of the factors that restricts the use of domestic reed canary grass as a bedding material is its low production and the resulting low availability of the raw material. In 2022, the total cultivation area of reed canary grass was only 2,700 hectares (OSF: Utilised agricultural area). Table 4 summarises the cultivation area of reed canary grass in the whole country and by

major region in 2022. Slightly more than half of this area is in Middle Finland, and roughly a fifth in Northern Finland. In 2022, a total of 300 farms produced reed canary grass (OSF: Utilised agricultural area). A little more than half were in Middle Finland. Based on the information presented in farmers' field subsidy applications for 2023 by 15 June, a total of 369 farms produced reed canary grass over an area of roughly 3,500 hectares. Of these, 343 farms reported that they produced reed canary grass for use as a bedding material and feed, while 26 reported that they produced it for use as energy. The cultivation area was slightly more than 3,100 hectares for reed canary grass for use as a bedding material and feed, and slightly less than 400 hectares for reed canary grass for use as energy.

Table 4. Reed canary grass cultivation areas and the number of reed canary grass farms in the whole country and by major region in 2022. Source: OSF: Utilised agricultural area.

	Whole country	Southern Finland	Western Finland	Middle Finland	Northern Finland
Reed canary grass cultivation					
Area, ha[1)]	2 700	300	400	1 400	600
Share of area under reed canary grass, %		11	15	52	22
Number of farms cultivating reed canary grass					
Farms, number	300	35	55	161	49
Share of the farms, %		12	18	54	16

[1)] In the statistics, the area is assigned entirely to the municipality in which the farm building is located, regardless of the location of the field. This affects the regional reed canary grass area.

Based on the 2022 cultivation area, the production potential of reed canary grass would be 10.8 million kg of dry matter when using the average dry matter yield of 4,000 kg per hectare. Because not all reed canary grass crops may necessarily be in the optimal production phase, it was realistic to calculate the estimate using a moderate average harvest level, even though the actual production potential could be much higher.

7.4. Hemp

Hemp (*Cannabis sativa*) is an annual crop which can legally be used to make fibres from the stem and press oil from seeds (Laine 2017). Hemp can best be grown in moist soil with a high organic content and with a pH of 6–7, or even a slightly alkaline pH (Laine 2017). In addition, the field must have a good structure and water balance. Harvesting is the most challenging phase in hemp production, especially with long-growing varieties. Hempseeds are harvested in the autumn, while hemp stems can be cut and harvested in the spring. The hemp stem consists of outer fibres and inner wood-like shives.

The fibre hemp (*Cannabis sativa subsp. sativa*) is primarily grown for its fibres, but shives can also be used. Fibres are typically extracted mechanically using fibre equipment to separate different types of fibres and shives from hemp mass. Shives can be used as a bedding material. Although fibres are the most valuable part of hemp, the use of shives is important for the profitability of production (Ikonen et al. 2015). The amount of shives generated as by-products of fibre production is almost twice that of each kilogram of fibres produced (1.7 kg of shives compared to 1 kg of fibres) (Ikonen et al. 2015). Typically, hemp produces roughly six tonnes of stems per hectare (Ikonen et al. 2015).

The oil hemp's stems can also be used as a bedding material. In this case, stems include the outer fibres and inner wood-like shives. The oil hemp's stems can be left without shredding during harvesting so that they can be used as a bedding material. However, the oil hemp typically produces less stem mass than the fibre hemp. One of the reasons for this is that the oil hemp is harvested as high as possible, even up to a height of one metre. Only half the stem is therefore harvested, and the remaining stem is left as stubble. The standing stems can be harvested using separate equipment attached to a combine harvester, but they are fairly expensive and require large harvesting areas. Another option is to cut the stubble in the autumn or alternatively in the spring, depending on weather, and harvest it for a bedding material use. This would also benefit hemp producers, as the stubble is usually crushed in the field.

Based on the information presented in farmers' field subsidy applications for 2023 by 15 June, the fibre hemp's cultivation area was slightly less than 400 hectares in Finland, which is insufficient for bedding material production on a commercial scale, at least at present. The oil hemp's area was larger than that of the fibre hemp, at roughly 1,100 hectares, while its bedding material yield after harvesting unfortunately remains small, at least when using current methods, which limits its harvest for a bedding material use.

When used as a bedding material, hemp binds moisture well and only generates a little dust. Hemp can be used shredded or pelleted. It is especially used as a bedding material for horses in the UK and Central Europe.

Currently, the bedding materials made from fibre hemp that are available on the market are imported, mainly from Europe. There is one company in Finland that is investing in developing the further processing of fibre hemp. Its goal is to build a fibre plant specialising in the processing of fibre hemp in Northern Ostrobothnia. Hemp production for use as a bedding material alone is not considered to be financially profitable. For production to be profitable, products with a higher processing value would be required, producing material suitable for use as a bedding material as a by-product. If the Finnish fibre hemp plant starts operating, it would enable the production of domestic hemp-based bedding materials. They would probably be used primarily for horses. Hemp is regarded as an unnecessarily expensive solution for use as a bedding material for cattle.

Hemp is not suitable as a bedding material for broilers (NoZoon project, Luke, unpublished results). In experimental pens when hemp and hemp-wood shavings mixture were used, clear lesions were found in the feet of birds, in contrast to birds raised on sphagnum moss and peat. In addition, in pens where hemp was used as a bedding the feather of the birds was dirtier than those of birds reared on sphagnum moss and peat, where only slight dirtiness was observed.

7.5. Bulrush

Bulrush (*Limnaecia phragmitella*) is a perennial wetland and coastal plant, which grows to a height of 1–3 metres. It is common in the whole of Finland except for Lapland (Laji.fi a). Bulrush is suitable for paludiculture. Based on the results of several studies, bulrush produces an average dry matter harvest of 9 tonnes per hectare (Lahtinen et al. 2022).

Its properties make bulrush a potential bedding material, while further research is required regarding its use as a bedding material. In trials, shredded bulrush has generated a large

amount of dust. Advancing the use of bulrush and using it extensively require the cost-effective development of paludiculture, harvesting methods, and the further processing of the entire harvesting chain and material. The primary purpose of harvesting it is to improve the status of water ways, and applications for use it in biochar and cement production is explored.

7.6. Common reed

Common reed (*Phragmites australis*) is a large perennial grass crop. It can grow to a height of 1–3 metres, and it forms large groups in wet growth locations. Common reed is common throughout the country: it is rare only in Northern Lapland (Laji.fi b). Common reed grows on the coasts of sea and lake areas. Up-to-date information about common reed areas is unavailable.

In Finland's conditions, common reed can produce up to 20 tonnes of dry matter per hectare, while the yield can vary significantly, depending on the growth location and conditions (Ikonen & Hagelberg 2008). The dry matter yields measured in certain trial areas have been an average of 5–7 tonnes per hectare (Ikonen & Hagelberg 2008). Common reed is also suitable for paludiculture.

In a comparison of bedding materials conducted using broilers, shredded common reed was unsuitable as a bedding material for birds (Da Silva Viana et al. 2022). In the trials, birds' feathers were dirtier than when using sphagnum moss or peat, in which case bird feathers were only slightly dirty. In addition, when using shredded common reed, significant damage was identified on the bottom of birds' feet, unlike when using sphagnum moss or peat, in which case practically no damage was found (Da Silva Viana et al. 2022).

Although a single study indicates that common reed is unsuitable for use as a bedding material for broilers, its properties make it a potential bedding material for other production animals and horses, but further research is required. If it was found to have good properties as a bedding material, and the aim was to expand its use as a bedding material, its large-scale use would require the cost-effective development of harvesting methods and the further processing of the entire harvesting chain and material.

8. Wood based materials

8.1. Wood shavings and sawdust

Wood shavings and sawdust are by-products generated at sawmills and planing mills during wood processing. They are suitable for use as a bedding material as such. Wood shavings are mainly generated at planing mills when processing dried timber mechanically. As its average moisture content is close to 10%, no separate drying is required. In contrast, the moisture content of sawdust generated when sawing fresh wood can be more than 50%, which reduces its suitability for use as a bedding material as such.

Alternatively, wood shavings and sawdust can be processed further to produce pelleted and pressed bedding materials. During pelleting, the temperature rises as a result of continuous pressing. The weight by volume of pelleted material is considerably higher than that of the raw material used, which enhances material transport and reduces costs. When wet, pellets expand into a soft and absorptive material. In various studies of different materials, pelleting has been found to significantly reduce the amount of dust generated from bedding materials (McClain et al. 1997, Fleming et al. 2008).

In addition, pellets made from fine grinding dust have been used as a bedding material for horses at least, but one of its disadvantages in practice is its wetting either in the stall or in the manure stock at the latest if there is a large amount of water.

Wood shavings and sawdust as such or pelleted are most commonly used as bedding materials for horses and dairy cows. They are also used to a lesser extent for poultry, mainly for laying hens. They are available as bulk material and packaged in bales. The advantages of bales are related to logistics and storage. Bales require less space than bulk material, which reduces transport costs and the need for storage space. Large commercial operators sell packaged products, whereas private operators mainly sell bulk material. Bales come in different sizes.

Fiercer competition for bedding materials is particularly reflected in the availability of wood shavings and sawdust, as they also have other uses, including energy generation. This is particularly evident during cold winters. In addition, wood shavings and sawdust produced at sawmills and planing mills have increasingly been delivered for energy generation, especially during this and last year, as materials suitable for heat production have been in short supply. The decreased availability of materials translates into higher prices. Near-future estimates of the availability of wood shavings and sawdust for use as bedding materials are not very positive. There will be a shortage of wood-based materials for heat production, as a result of which smaller amounts of wood shavings and sawdust will be available for use as bedding materials. According to one significant seller of wood-based bedding materials, the amounts of wood shavings and sawdust will be sufficient for use as bedding materials in the autumn, after which their availability will end or at least decrease significantly, as they will mostly be used in heat production.

8.2. Willow

The structural and chemical properties of willows (*Salix* spp.) make them potential bedding materials. When chipping willows through a sieve of a couple of centimetres, the result is a fine-grained, porous and absorptive material, which could be used as a bedding material. The natural components and antimicrobic compounds that can be obtained from willow bark and may prevent harmful microbes growing could produce added value in the use of willows as a bedding material. Even through willows are used as a bedding material for livestock in Europe, at least on a small scale, very little information is available about their properties as a bedding material. In a broiler study conducted by Luke, no differences were identified in the production results of birds between willow chips and other materials. However, birds' foot health was poorer, and the percentage of completely healthy feet halved compared to the use of peat. In addition, bird feathers were also dirtier than when using peat (NoZoon project, Luke, unpublished results). The use of willow as a bedding material for broilers and other livestock calls for further research.

Short rotation is one production method for willow. This means quickly growing willows produced from shoots are grown densely to produce the largest possible biomass during a short rotation (Viherä-Aarnio 2022). The total age of a willow orchard grown using the short rotation method is 19–25 years, and it produces six to eight harvests (Aro 2022). Aboveground parts of willows are harvested every three to five years (Aro & Kekkonen 2022a). The first harvesting can be carried out after roughly three years (Aro & Kekkonen 2022b). In Finland's climate conditions, the potential dry mass yield of willows grown on farmland is estimated to be 6.8 tonnes per hectare (Mola-Yudego 2010). According to the estimate of Heino and Hytönen (2016), the willow cultivation area was roughly 110 hectares in Finland in 2015, but the current area is not accurately known (Jylhä & Viherä-Aarnio 2022).

If suitable bedding materials were obtained from willows, they could improve certain farms' self-sufficiency in bedding materials, as willows can be grown in various types of soil in southern parts of Finland. In addition, some farms could specialise in the commercial production of willows. However, the use of willows to produce the highest value added products possible, including biochar, may limit their availability for use as a bedding material.

8.3. Wood fibre

Wood fibre is a new type of bedding material, the commercial production of which has only recently started in Finland. Wood fibres are typically obtained from side streams of the sawmill industry that are further processed into products suitable for use as bedding materials through chipping, grinding and pressurising. Wood fibre is a lightweight material. On the markets, wood fibres are sold as such or mixed with other materials, mainly peat and peatland biomass.

8.4. Forest industry sludge

The forest industries, or the wood processing industries, consist of the pulp, paper and board industry and the wood product industry. The pulp, paper and board industry covers the production of chemical and mechanical pulp, paper and board, generating sludge as a by-product.

Fibre-based sludge is a hygienic and nutrient-poor material that originates in the pre-purifier of process water during drying and is separated as semi-hard pulp through screening. It consists of cellulose fibres that are too short for use in making pulp mills' end products.

Fibre-based sludge can be used as such as a soil improvement agent, provided that it meets the criteria set out in the fertilising product regulation. It is also a potential bedding material. Because the typical dry matter content of fibre-based sludge is less than 30%, it must be dried before use as a bedding material. The properties and amounts of fibre-based sludge make it a potential bedding material. However, further research is required.

9. Manure-based bedding materials

9.1. Recycled manure solids

Dry solids and liquids are filtered out in the separation of manure. Slurry is separated most commonly, but dry manure can also be separated. The dry solids generated during separation can be used as a bedding material. Currently, dry solids separated from slurry are only used as bedding materials for cattle. The possible use of separated manure as a bedding material for other animals as well requires research.

The dry matter content of the dry solids separated from slurry intended for use as a bedding material should be roughly 35% (Green et al. 2014). A sufficient dry matter content can be achieved using a separator designed specifically for the production of bedding materials. Dry solids can be used as bedding materials as such or after composting. However, not all countries permit the use of composted dry solids as bedding material due to the risk of heat-resistant microbes (e.g. the UK, AFPA 2016). To guarantee an even composting quality, use of drum composter is recommended. Composting increases the dry matter content of dry solids, but it also reduces the number of microbes. However, this impact is only temporary, and in use, the number of microbes will quickly reach the same level as in freshly used dry solids (Cole & Hogan 2016). Separated manure should be used as fresh as possible, and it cannot be allowed to heat during storage or use. This also applies to composted dry solids.

The ground rule is that a single dairy cow produces as much manure per year as it requires for its annual bedding consumption. According to Pyykkönen (2023), the amount of dry solids separated from slurry depends largely on the dry matter content of slurry and the targeted dry matter content of dry solids, which can be regulated through separator settings, especially by adjusting the compressive force of a screw separator. Furthermore, the particle size distribution and the liquid retention capacity of particles have an impact on separation results (Pyykkönen 2023). Preliminary results calculated by Pyykkönen (2023) in the OrVo and FarmGas-PS 2 projects are presented below. If the dry matter content of slurry is 6%, and dry solids with a dry matter content of 31% are produced, 6% of the fed slurry will be separated into dry solids, and the remaining 94% into liquids. If the dry matter content of slurry is lower, roughly 5%, while the targeted dry matter content of dry solids is higher, 35%, only 2–3% of slurry will be separated into dry solids. Significantly larger amounts of dry solids can be generated from thicker slurry. For example, 8–9% of slurry with a dry matter content of 8% are separated into dry solids, even if a higher dry matter content (40%) is targeted. The separation of dry manure is still a new method in Finland, and no Finnish research results are available.

Naturally, dry solids separated from slurry contain more microbes than other bedding materials (Bradley et al. 2018, Beauchemin et al. 2022). This must be taken into account, especially with dairy cows, as bedding material is one of the most significant sources of microbes on the surface of udders (Rowbotham & Ruegg 2016a). In the risk management of dry solid bedding, proper bedding material management and hygiene are key factros. Dry solid bedding is not recommended on farms where the initial status of animal health is poor.

Using separated slurry or manure produced on a farm as a source material for bedding materials is not expensive after the initial investment costs and makes the farm self-sufficient in bedding materials. Slurry and dry manure need to be separated using different equipment. However, farms should have a backup plan for bedding in the event of the spread of infectious animal diseases. In addition, clear guidelines should be prepared for the use of

separated manure as a bedding material to minimise risks associated with food hygiene and animal health, as has been done in the UK, for example (AFPA 2016).

9.2. Dry horse manure

Horse manure has a high bedding material content and is therefore dry, and it has been used to some extent in cattle bedding underneath straw. It has also been used as a bedding material in bedding material studies conducted for cattle (Manni & Huuskonen 2021b, Tuomisto et al. 2021). Compared to plant stem materials, dry horse manure was much less preferred bedding for lying down for cattle (Tuomisto et al. 2021). One of the reasons for this may have been the high moisture content of the material. In addition, the use of the material may have required habituation from animals, as the differences between dry horse manure and plant stem materials evened out as the trial progressed (Tuomisto et al. 2021). However, this type of manure may involve hygiene risks, which must be taken into account when using it as a bedding material.

9.3. Amount of manure accumulated in Finland

Approximately 13 million tonnes of manure are accumulated annually in Finland (Luostarinen et al. 2017a,b, Lemola et al. 2023, Luostarinen et al. 2023). The amount of manure is based on the Finnish normative manure system (Luostarinen et al. 2017a,b). The amount of manure consists of manure removed from livestock buildings, from which the average amount of manure ending up in pastures and outdoor pens has been deducted (Luostarinen et al. 2017a; Lemola et al. 2023).

Table 5 summarises the amount of manure accumulated annually in Finland by animal species. Cattle account for a significant part of all manure, as roughly 75% of the amount of manure comes from cattle farms (Luostarinen et al. 2023). The amount of manure generated annually is roughly 9.8 million tonnes for cattle, 2.1 million tonnes for pigs, 0.6 million tonnes for horses and ponies, and 0.3 million tonnes for poultry. Figure 9 presents the amounts of slurry generated annually on livestock farms, and Figure 10 presents the amount of dry manure by main production and major region.

Table 5. The amount of manure accumulated in Finland by animal species and type of manure. The information is based on the Finnish normative manure system (Luostarinen et al. 2017a,b).

Animal species	Volume, t
Manure of horses and ponies (solid)	643 840
Manure of sheep and goats (solid)	109 734
Manure of laying hens (solid)	98 818
Manure of other poultry (solid)	143 042
Cattle slurry	5 396 056
Cattle dry manure	3 567 147
Cattle urine	789 044
Pig slurry	2 004 468
Pig solid manure	46 860
Pig urine	48 523
Manure of fur animals (solid)	111 551
Total	**12 959 083**

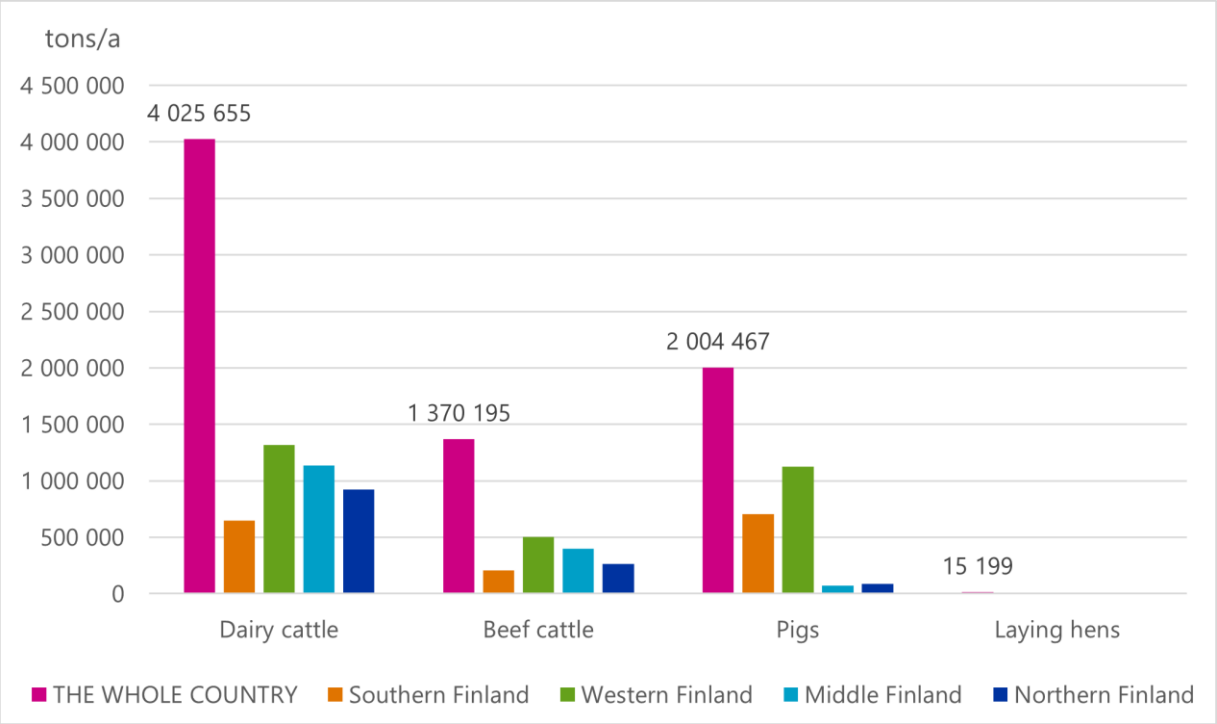


Figure 9. The amount of slurry generated annually on livestock farms by main production and major region in 2020. Source: Biomass Atlas map service, Luke.

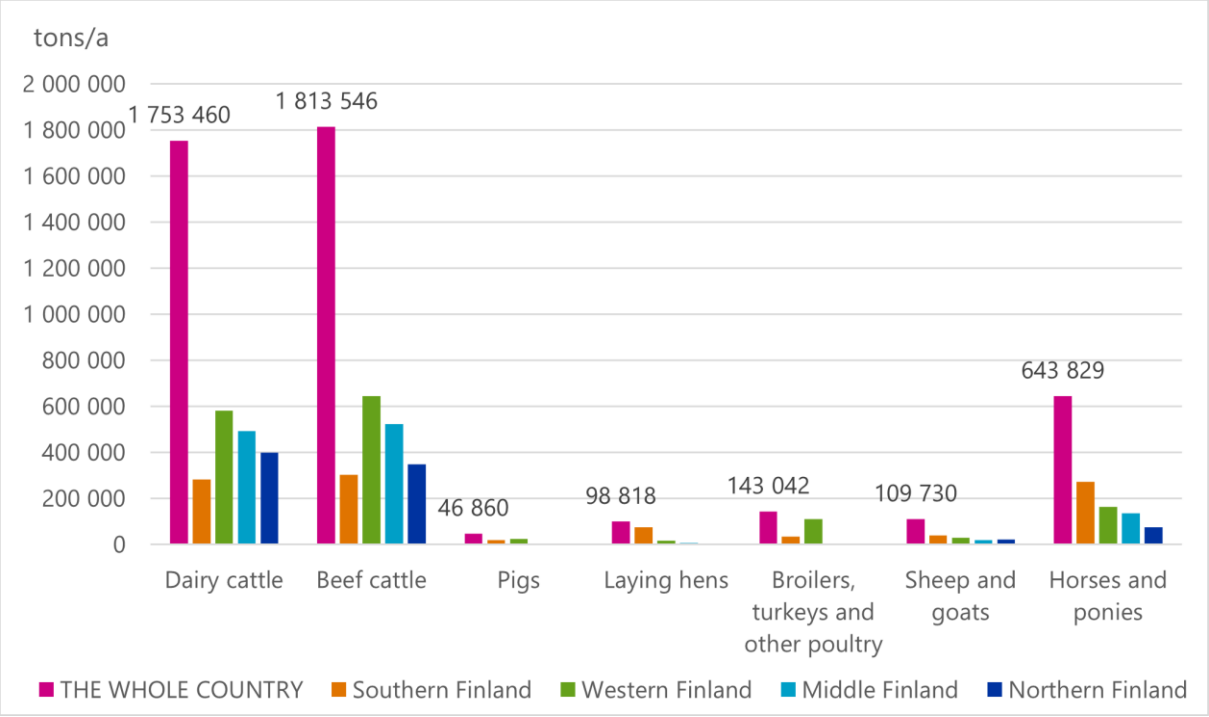


Figure 10. The amount of dry manure generated annually on livestock farms by main production and major region in 2020. Source: Biomass Atlas map service, Luke.

10. Other bedding materials

10.1. Peatland biomasses

Of peatland biomasses, sphagnum moss has properties that make it a potential bedding material. It partly resembles peat, being porous and soft, and it has a high liquid retention capacity. Sphagnum moss has been tested as a bedding material for broilers, with good results (Da Silva Viana et al. 2022). Based on the results, it is on a par with peat as a bedding material.

Sphagnum moss grows as a layer of at most 30 cm thick on the surface layer of peatlands. It grows by roughly 1 cm per year.

When extracting sphagnum moss, living sphagnum moss is removed from the surface layer of peatlands so that new moss starts to grow afterwards. According to estimates, sphagnum moss recovers in roughly 30 years after extraction, while there may be significant variation between peatlands (Silvan et al. 2017). The recovery rate is especially affected by the extraction depth and the amount of remaining sphagnum moss (Silvan et al. 2019). Considering regrowth, the suitable extraction depth depends on the peatland due to changes in the thickness of the sphagnum moss layer. However, a maximum extraction depth of 30 cm is generally recommended (Silvan et al. 2019). The average yield of sphagnum moss has been 1,000 m^3 per hectare on average, as reported by Silvan et al. (2019).

Between 2016 and 2021, sphagnum moss was extracted over roughly 160 hectares mainly in the regions of Southern Ostrobothnia, Pirkanmaa and Satakunta (Ministry of the Environment 2022). During the production phase, sphagnum moss has a very high moisture content of roughly 80%. It can only be used as a bedding material after drying. Drying can take place outdoors in the field or in an industrial process. However, large-scale field drying of sphagnum moss is considered unrealistic, as it would require large paved areas, and the dry matter content could not be raised sufficiently to prevent any subsequent heating. Preventing subsequent heating is important for sphagnum moss to maintain its good properties as a bedding material.

The extraction of sphagnum moss requires further development especially regarding extraction methods. Furthermore, drying sphagnum moss for use as a bedding material is another bottleneck in its large-scale use. When extracting sphagnum moss, nature values and the climate and environmental impact must be addressed, as its extraction may permanently alter conditions in the growth location. Sphagnum moss should therefore only be extracted from peatlands with low nature values (Silvan et al. 2019). It is estimated that there are roughly 280,000 hectares of drained peatlands suitable for sphagnum moss extraction and unprofitable for forestry (Silvan et al. 2017).

10.2. Sand

Sand is mainly used as a bedding material in deep stalls for dairy cows and to some extent in deep bedding areas. Sand stalls are still fairly rare in Finland (Kuikka & Tavastjerna 2018), even though they are fairly common in other parts of the world.

The advantage of sand stalls is that as an inorganic material, sand contains fewer microbes than organic bedding materials (Bradley at al. 2018). In addition, they are comfortable and maintain high hock health in cattle.

The disadvantage is their laborious maintenance (Alasuutari & Palva 2014). Furthermore, sand is not usually directly suitable for Finland's typical sludge systems without any special technical solutions (Kuikka & Tavastjerna 2018), in addition to which sand wears down barn equipment (Frondelius et al. 2019). Sand also settles at the bottom of the sludge tank, causing additional work and costs if the tank must be drained using an excavator, for example. If sand is moist, it may freeze in winter.

Each farm must find the sand that suits it best. However, the grain size should be at least 2 mm. The price of sand bedding depends on the sand transport distance (Kuikka & Tavastjerna 2018). While sand can be recycled from sludge for reuse as a bedding material, this reduces the microbiological quality of sand (Rowbotham & Ruegg 2016b).

10.3. Paper

The paper used in newspapers has properties that make it a potential bedding material. This has been identified in studies of the properties of various types of paper (shredded, cut, pelleted) and their use as a bedding material especially for horses and cattle (McClain et al. 1997, Ward et al. 2000, Ward et al. 2001, Ward & Wohlt 2002).

Large amounts of paper waste are still generated in Finland. Paper waste is used on a large scale in making kitchen and toilet tissues and insulation products. Previously, roughly half the paper waste collected in Finland was delivered to the UPM mill in Kaipola, Jämsä in Middle Finland. After it was shut down in 2020, new uses have been investigated for paper waste because the Kaipola mill left a large gap.

A challenge in using paper waste as a bedding material is that it contains large amounts of magazines and office paper. Their surface has been treated with clay, which reduces the properties of paper as a bedding material, absorption in particular, compared to the paper used in newspapers. In addition, the ink and colourants used in certain printed paper grades may contain harmful substances, whose harmfulness cannot be eliminated in shredding without deinking.

11. Survey on the use and availability of bedding materials

In the spring of 2023, Luke conducted a survey on the use and availability of bedding materials. The survey was targeted at livestock farms and horse stables, and it was conducted as a Webropol survey between 19 April and 7 May 2023. Its primary goal was to identify the use and availability of various bedding materials, user experiences and the future outlook for bedding material supply.

11.1. Background details of the respondent

The survey had 441 responses. Examined by the major regions, responses were received fairly comprehensively from all regions (Figure 11). Most responses were received from the regions of Western and Southern Finland, and the least from Northern Finland. The respondents' regional distribution was also very close to the geographic distribution of all agricultural and horticultural enterprises in Finland (Luke's statistics 2023).

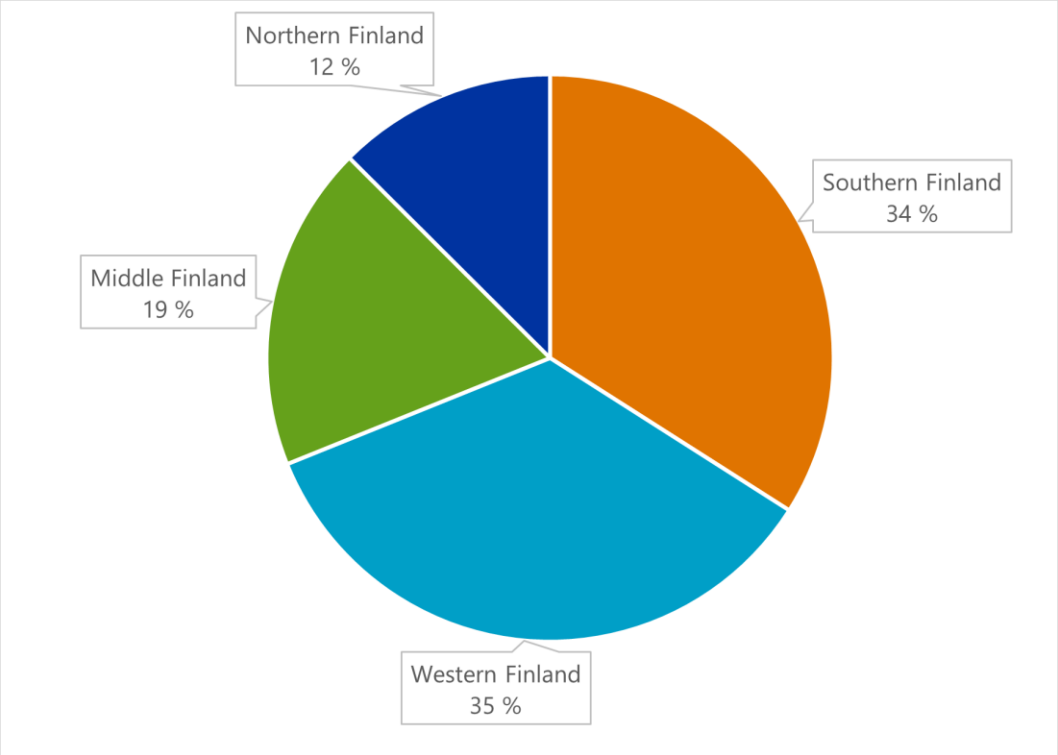


Figure 11. Distribution of respondents to the bedding material survey by major region.

Responses were received comprehensively from all main productions in livestock production (Figure 12). The highest number of responses was received from respondents engaged in horse, cattle and poultry meat production. Of all main productions, the "other" category included broiler and turkey breeder production, alpaca production, nature management and animal-assisted services.

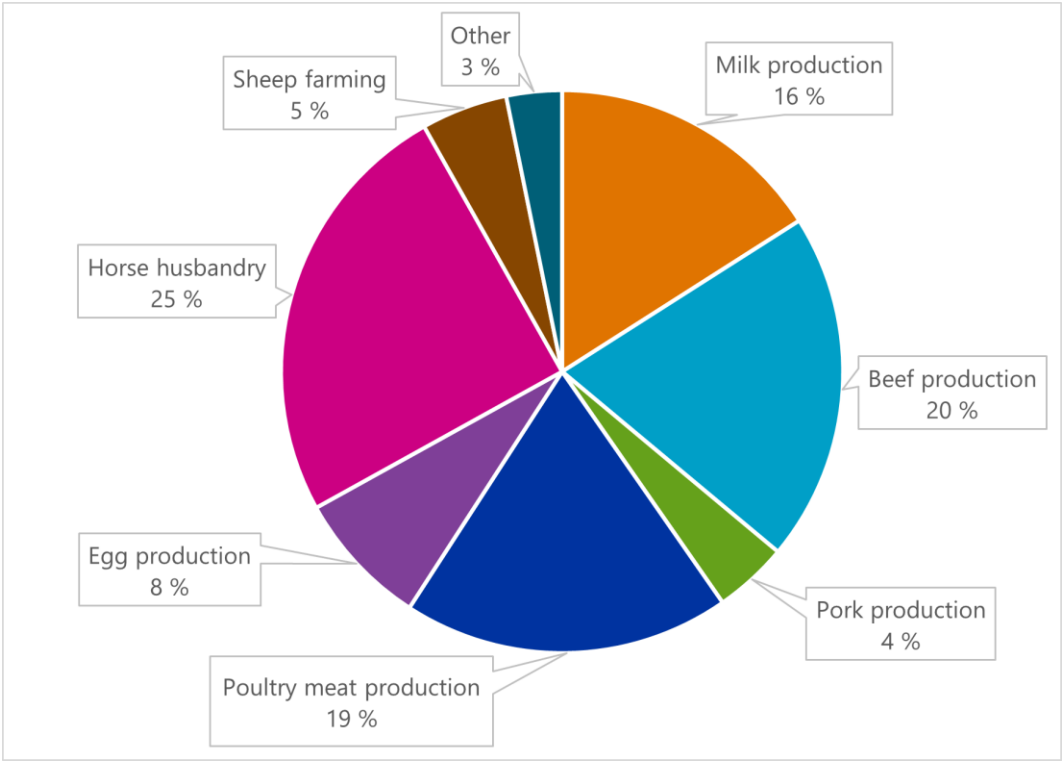


Figure 12. Distribution of respondents to the bedding material survey by main production.

The size of the responding farms, with the average number of animal keeping sites, is presented in Table 6. Responses were received from farms of all sizes, ranging from very small to large units. The median presented in the table represents the typical size of the responding farms, which differs from the average size in some situations.

Table 6. Average number of animal keeping sites on the responding farms.

	Number of animal places, average, pcs	Number of animal places, median value, pcs	Number of animal places, min and max, pcs
Dairy cows	103	75	20–600
Growing cattle (including heifers reared as dairy cows)	112	50	2–1 200
Suckler cows	69	60	2–300
Pigs	1 017	1 000	250–2 999
Meat poultry	84 927	65 000	6–900 000
Laying hens	12 521	6 000	4–180 000
Horses and ponies	8	5	1–49
Sheep	73	45	2–320

11.2. Use of different bedding materials on livestock farms

The survey requested information about the primary bedding material. The respondents were able to select one or more options. The figures presented in the graphs therefore do not add up to 100%, as some farms used more than one bedding material. The respondents were also able to give an open-ended response if the list of bedding materials did not include the correct option or to select the "no bedding materials used currently" option. Based on the responses, peat was clearly the most commonly used bedding material (Figure 13). It accounted for 40% of all bedding materials. It was followed by straw (24%) and wood shavings (18%). All other bedding materials made up less than 10% of all bedding materials used.

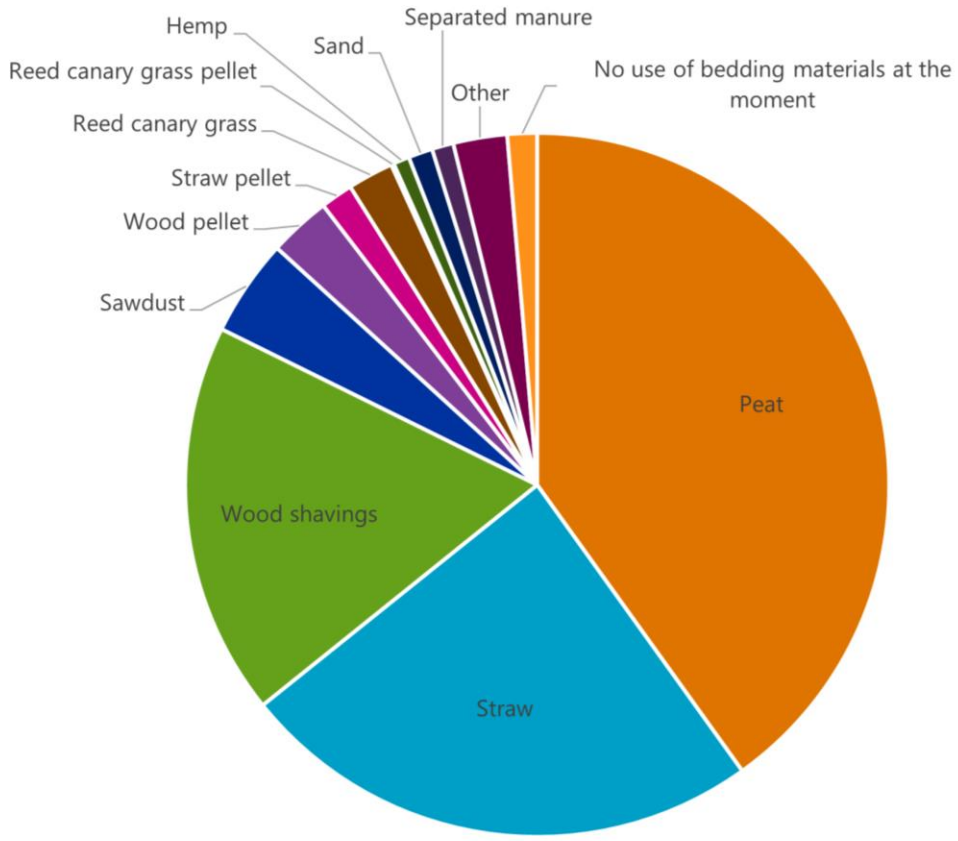


Figure 13. Distribution of primarily used bedding materials.

Peat was the most commonly used bedding material in all main productions except for egg production and sheep farms (Table 7). Wood shavings were the most commonly used bedding material in egg production, and straw in sheep farming. Wood shavings were also used to some extent in poultry meat production, as almost a quarter of all respondents selected wood shavings as their bedding material option. Alongside peat, straw was a significant bedding material used on cattle farms, and wood shavings were especially used on dairy farms. Separated manure was only used on milk production farms. The broadest range of bedding materials was used in horse husbandry, which corresponded to the results of previous studies. In sheep farming, the use of bedding materials other than those given as options in the survey was also common, as roughly a quarter of all farms indicated that they used other bedding materials. In the open-ended responses, the "other" option was mainly indicated to be dry hay, while a mixture of peat and wood shavings, sunflower pellets, and chipped branches were also mentioned.

Table 7. Popularity of bedding materials used on farms by main production; percentage of respondents using each bedding material by main production. The respondents were able to select one or more options.

	Milk production %	Beef production %	Pork production %	Poultry meat production %	Egg production, %	Horse husbandry %	Sheep farming, %	Other, %
Peat	70	82	73	83	17	59	47	71
Straw	61	74	27	2	11	36	82	36
Wood shavings	41	11	27	24	60	35	53	29
Sawdust	4	2	-	3	14	17	12	-
Wood pellet	-	1	-	-	3	17	-	7
Straw pellet	-	-	-	-	-	10	-	-
Reed canary grass	4	8	-	-	-	2,5	12	7
Reed canary grass pellet	-	-	-	-	-	1	-	-
Hemp	-	-	-	-	3	2,5	12	-
Sand	1	6	-	-	-	2	-	-
Separated manure	8	-	-	-	-	-	-	-
Other	1	10	-	-	-	3	24	7
No use of bedding materials at the moment	1	1	-	-	23	-	-	7

At the time of responding, farms may have used several different bedding materials. Because the question aimed to identify the materials used generally on a farm or in a stable, it is impossible to say whether the materials were used simultaneously for specific animals or at different times for specific or different animals.

In milk and beef production in particular, farms used several different bedding materials. A total of 70% of beef producers and 65% of milk producers stated that they mainly used two or more bedding materials. Peat and straw or peat, straw and wood shavings were the most commonly used bedding materials in beef production. All farms that used sand also used another bedding material, including peat, straw or both. Milk producers most commonly used peat and straw, wood shavings and straw, or all three. Half of farms using separated manure also used another bedding material, including straw or peat. Different animal groups on a farm and different animal areas in production buildings are probable reasons for cattle farms commonly using several types of bedding materials. For example, peat or dry solids are typically used in stalls for dairy cows, while straw is used in pens and other deep bedding areas. In addition, the use of bedding materials as mixtures increases the use of several bedding materials.

In poultry meat production, only a tenth of all farms used several bedding materials. If several bedding materials were used in poultry meat production, they were almost without exception peat and wood shavings or sawdust. In egg production, two or more bedding materials were used on more than a fifth of all farms. The use of straw and wood shavings or peat and wood shavings was most common.

In pork production, a quarter of all farms responded that they used two different bedding materials at the same time. The most common combination was peat and straw.

In sheep farming, only one respondent stated that they only used hemp as a bedding material, whereas all others responded that they used straw, reed canary grass or hay, and peat, wood shavings or sawdust.

In horse husbandry, almost 60% of all respondents stated that they used two or more bedding materials. The most common were peat and straw, peat and wood shavings, or straw and wood shavings. The use of various pellets was usually selected in combination with other bedding materials.

11.2.1. Amounts of bedding materials used

The average amounts of peat used annually by main production and region are presented in Table 8. In addition, the table presents the median, as well as minimum and maximum, amounts.

Table 8. Annual amounts of bedding peat used annually per farm by main production and major region.

	Average volume used per farm, m^3/a	**The median value of volume used per farm, m^3/a**	**The min and max volume used per farm, m^3/a**
MAIN PRODUCTION			
Milk production	539	400	5–3 000
Beef production	879	400	9–7 000
Pork production	921	600	100–2 500
Poultry meat production	742	700	30–2 100
Egg production	62	50	1–130
Horse husbandry	349	50	1–10 000
Sheep farming	38	50	14–50
Other	207	150	2–500
MAJOR REGION			
Southern Finland	481	200	2–10 000
Western Finland	808	615	1–7 000
Middle Finland	558	250	3–5 000
Northern Finland	411	188	2–2 700

Table 9 presents the amounts of common bedding materials other than peat by major region. The figures are presented in cubic metres, bales and/or kilograms, depending on how each material is normally sold and purchased. The fact that bales came in various different sizes and weights made it especially difficult to interpret the results. Significant variation in the weight by volume of different materials depending on the density of the packaging/storage solution or the moisture content made it challenging to interpret amounts based on amount. For certain materials, there were so few respondents that it makes no sense to present any figures. When examined by region, differences in delivery and packaging methods can be identified. In Southern Finland, the majority of all respondents, almost 80%, acquired wood shavings in bales, whereas the situation was completely the opposite in Western

Finland, where 80% of all respondents acquired them as bulk material. The division was less clear-cut in Middle and Northern Finland, in which both delivery and packaging methods were equally common.

Table 9. Average amount of other bedding materials used annually per farm by major region.

Bedding material	Major region	Average volume used per farm, m^3/kg/bale (pcs) annually	The median value of volume used per farm, m^3/kg/bale (pcs) annually	The min and max volume used per farm, m^3/kg/bale (pcs) annually
Wood shavings	Southern Finland	244 m^3	120 m^3	15–700 m^3
		260 pcs	100 pcs	5–2 300 pcs
	Western Finland	287 m^3	253 m^3	0,5–800 m^3
		706 pcs	495 pcs	35–1 800 pcs
	Middle Finland	588 m^3	290 m^3	20–2000 m^3
		377 pcs	140 pcs	10–1 800 pcs
	Northern Finland	107 m^3	45 m^3	15–400 m^3
		105 pcs	75 pcs	20–220 pcs
Straw	Southern Finland	62 480 kg	15 000 kg	200–425 000 kg
		220 pcs	70 pcs	2–1 500 pcs
	Western Finland	21 333 kg	20 000 kg	4 000–40 000 kg
		286 pcs	175 pcs	1–1 200 pcs
	Middle Finland	132 500 kg	132 500 kg	15 000–250 000 kg
		281 pcs	125 pcs	10–2 000 pcs
		128 pcs	80 pcs	1–700 pcs
Sawdust	Southern Finland	27 m^3	27,5 m^3	5–48 m^3
		28 pcs	20 pcs	15–50 pcs
	Western Finland	33 m^3	11 m^3	1–108 m^3
		125 pcs	125 pcs	50–200 pcs
	Middle Finland	73 m^3	10 m^3	8–200 m^3
		95 pcs	95 pcs	50–140 pcs
	Northern Finland	41 m^3	41 m^3	12–70 m^3
Wood pellet	Southern Finland	13 208 kg	2 000 kg	1 000–60 000 kg
	Western Finland	3 500 kg	3 500 kg	1 000–6 000 kg
	Middle Finland	38 000 kg	38 000 kg	6 000–70 000 kg
	Northern Finland	2 875 kg	2 250 kg	1 000–6 000 kg
Straw pellet	Southern Finland	12 417 kg	6 750 kg	1 000–48 000 kg
	Western Finland	-	-	-
	Middle Finland	-	-	-
	Northern Finland	2 250 kg	2 250 kg	1 000–3 500 kg
Reed canary grass	Southern Finland	-	-	-
	Western Finland	-	-	-
	Middle Finland	152 pcs	135 pcs	15–500 pcs
	Northern Finland	45 pcs	45 pcs	40–50 pcs

11.3. Regional distribution in the use of bedding materials

Examined by regions, peat was the most common bedding material, followed by straw and wood shavings in all regions (Figure 14). Other bedding materials showed more regional variation, with the use of reed canary grass much more common in Middle Finland than in other regions, for example. The more significant use of reed canary grass in the region of Middle Finland compared to other regions was probably at least partly affected by its production taking place in the same region. A total of 52% of the reed canary grass cultivation area and 54% of all farms producing it are in Middle Finland (Table 4). The use of sawdust was more common in Middle and Northern Finland than in other regions.

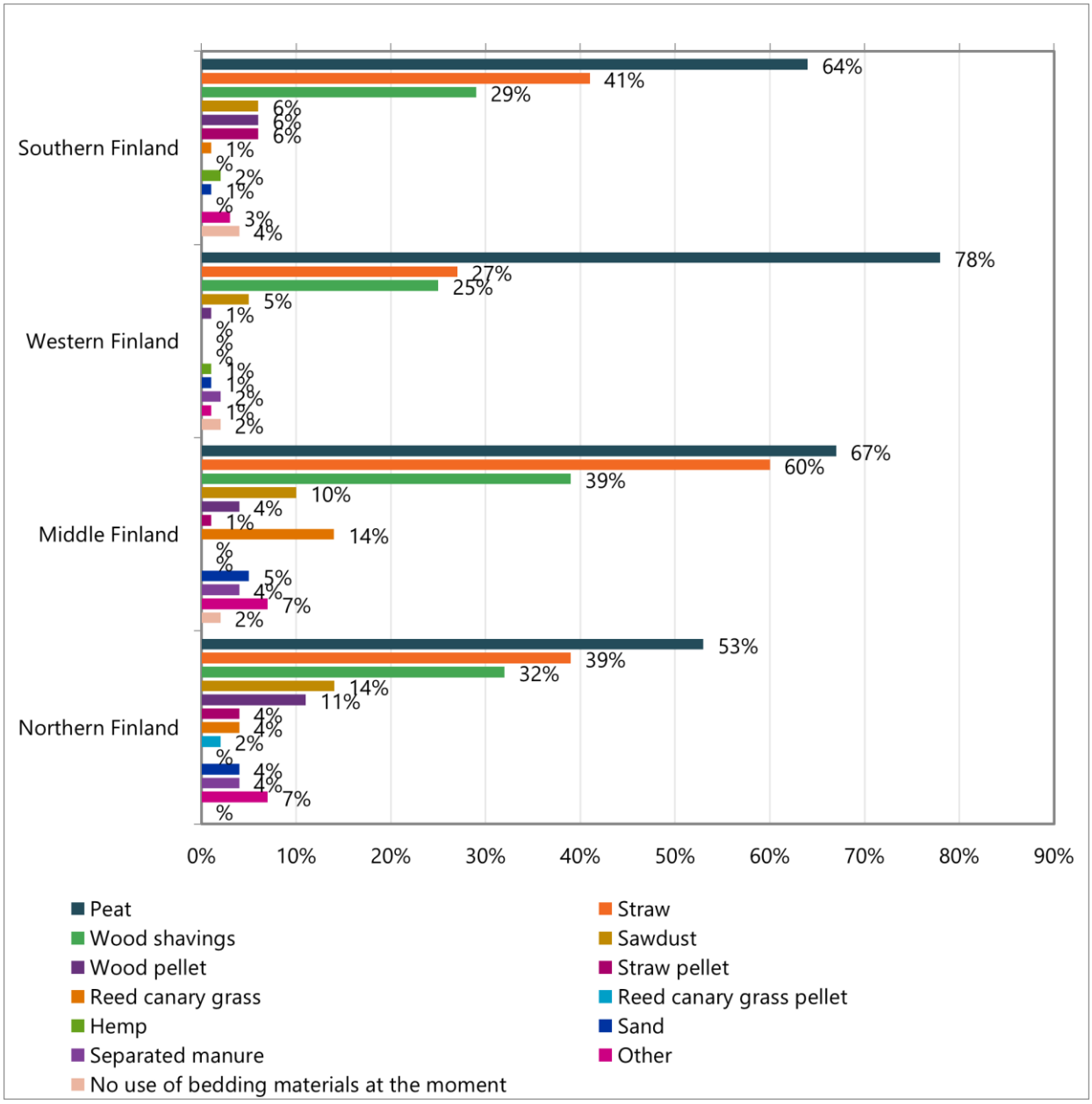


Figure 14. Use of different bedding materials by major region.

11.4. Origin of bedding materials

Regarding the question of the origin of bedding materials, the respondents were able to select one or more options, which is why the figures do not add up to 100%. Most respondents used bedding materials of a domestic origin (Figure 15). On farms that indicated pork and poultry meat production as their main production, the bedding materials used were 100% of domestic origin. Most foreign bedding materials were used in horse and sheep farming. Foreign bedding materials included straw pellets, wood shavings, peat and hemp in particular.

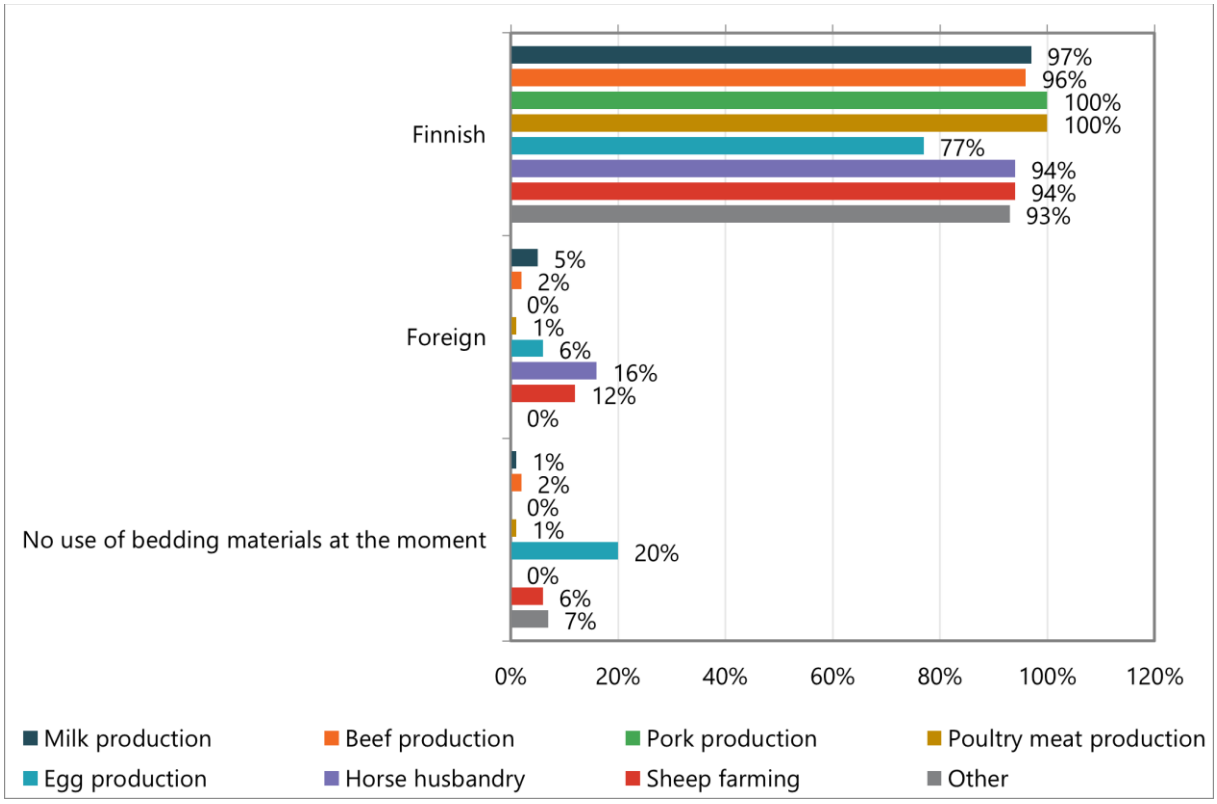


Figure 15. Country of origin of bedding materials by main production.

Examined by region, there were no significant differences in the countries of origin, as bedding materials of a domestic origin formed the largest group in all regions (Figure 16). Southern Finland only stood out in that foreign bedding materials accounted for a slightly higher percentage than in other regions. This may have been affected by the geographical location and its impact on transport costs, and partly by Southern Finland being home to the largest number of horses and horse keeping sites.

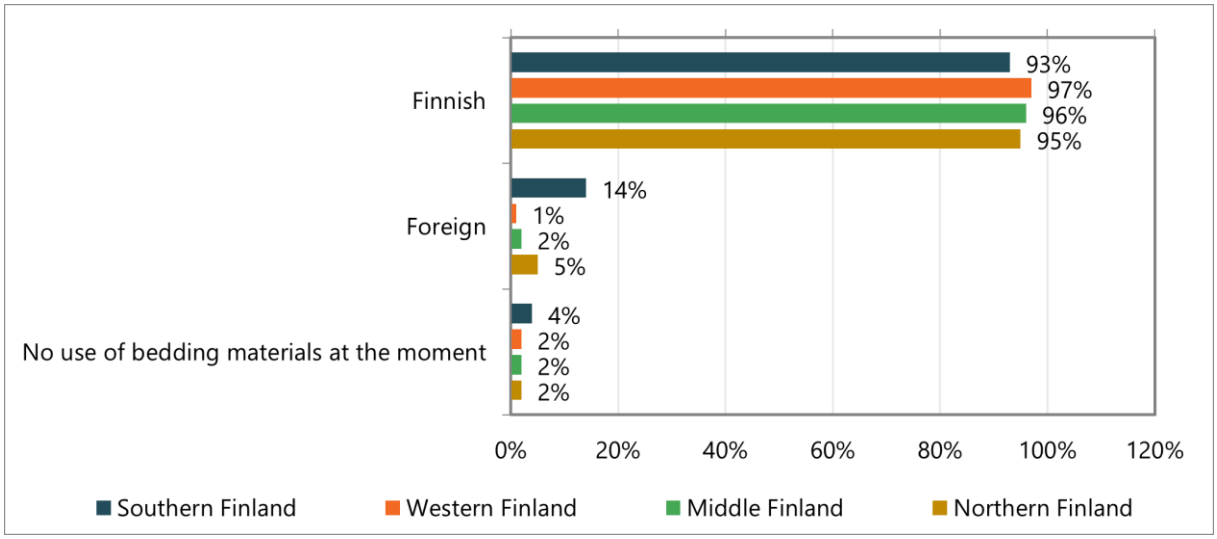


Figure 16. Country of origin of bedding materials by major region.

11.5. Use of bedding materials

In questions regarding production buildings and bedding methods, the respondents were able to select one or more options, and each farm could have several main productions, which is why the figures do not add up to 100%. In pig and poultry farming, an insulated production building was most common, whereas in other main productions, a partly or wholly uninsulated building was as common as or more common than an insulated building. In beef production, an uninsulated building was significantly the most common, unlike in other main productions (Figure 17).

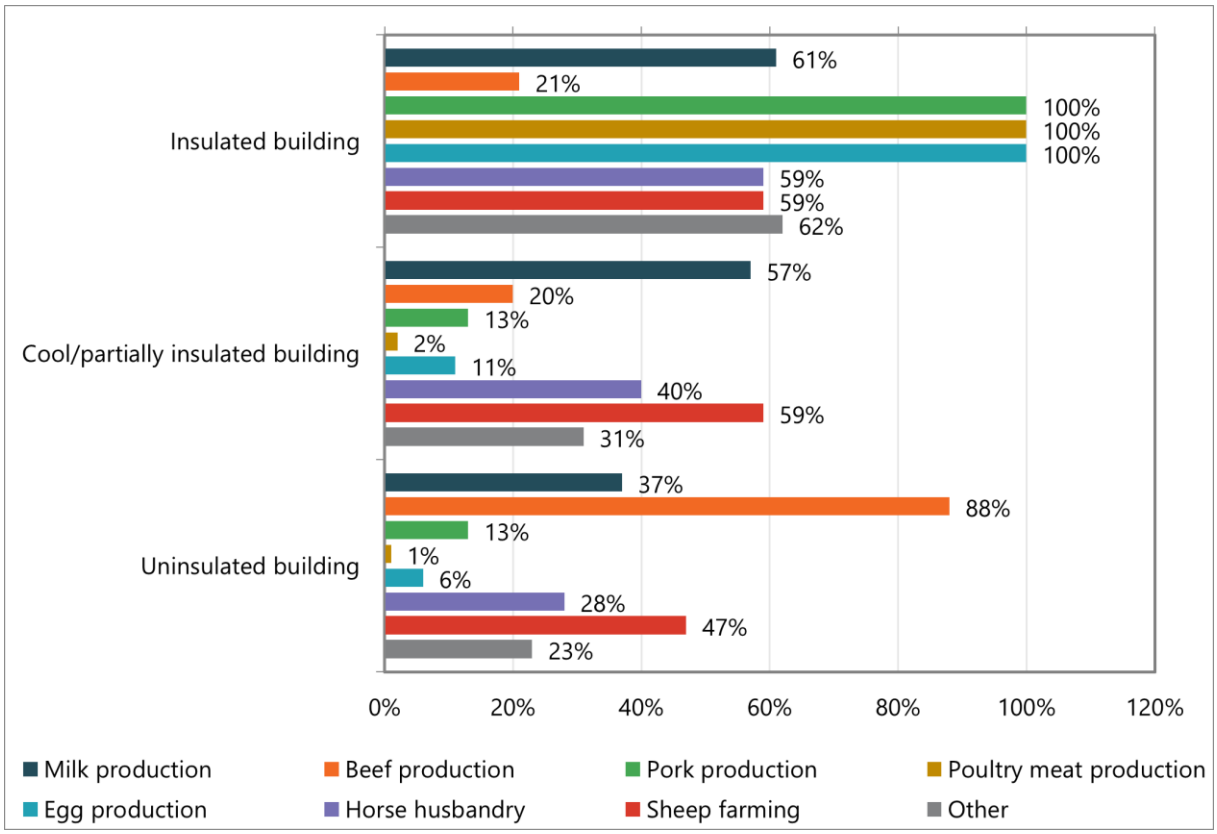


Figure 17. Production building type by main production.

The uses of bedding materials showed slight differences between main productions (Figure 18). A deep bedding to which bedding materials were added regularly was a common bedding method especially in cool and uninsulated production buildings and on cattle and sheep farms. This was also a common method in horse husbandry and egg production. In egg production, a deep bedding to which no bedding materials were added during a production batch was almost as common. This was significantly the most common method in poultry meat production. A bedding mattress to be cleaned and replenished every day was the most common method in horse husbandry. The majority of milk producers and some pork producers indicated a solid surface stall cleaned every day as their bedding method. The use of bedding materials solely as enrichment was significantly the most common in pork production.

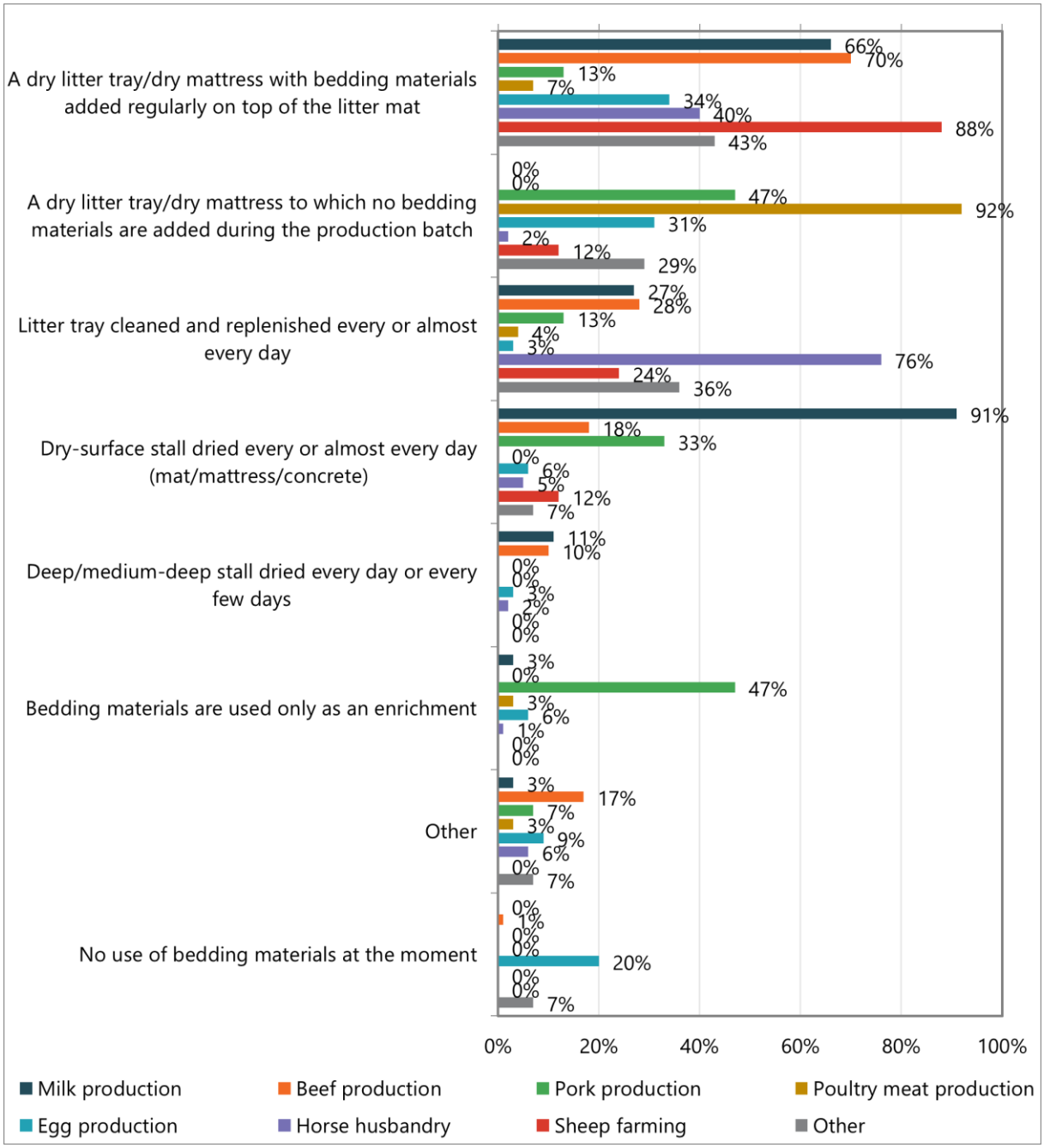


Figure 18. Use of bedding materials by main production.

11.6. Quality and availability problems with bedding materials

The respondents were asked whether they had faced any quality and/or availability problems with bedding materials during the last 12 months. In addition, they were asked to describe any quality defects and availability problems, as well as consider the reasons for them. Most respondents (76%) had not identified any quality problems with bedding materials during the last 12 months. However, a fifth of all respondents (21%) reported quality problems.

Quality problems were most common in horse husbandry and on milk production farms (Figure 19). Nearly all quality problems were associated with the three most commonly used bedding materials – peat, wood shavings and straw – and mostly with peat. The generality of quality problems related to these bedding materials can at least partly be explained by their extensive use. Reasons for quality problems with peat included a moisture or degree of decomposition dirt content that was too high and a large number of stumps and sticks, including ground plastic in some situations, mixed with peat. Some respondents stated that they had had to accept lower-quality peat to have at least some bedding material, while a few respondents indicated that they had been forced to use peat intended for heat production, as no bedding peat had been available. Users of wood shavings mostly reported dust issues and a composition that was too fine-grained. Problems with straw included dust, moisture and mould. Unfavourable weather conditions for harvesting were regarded as the key reason for problems with straw. Of all respondents, 3% could not say whether there had been any quality problems.

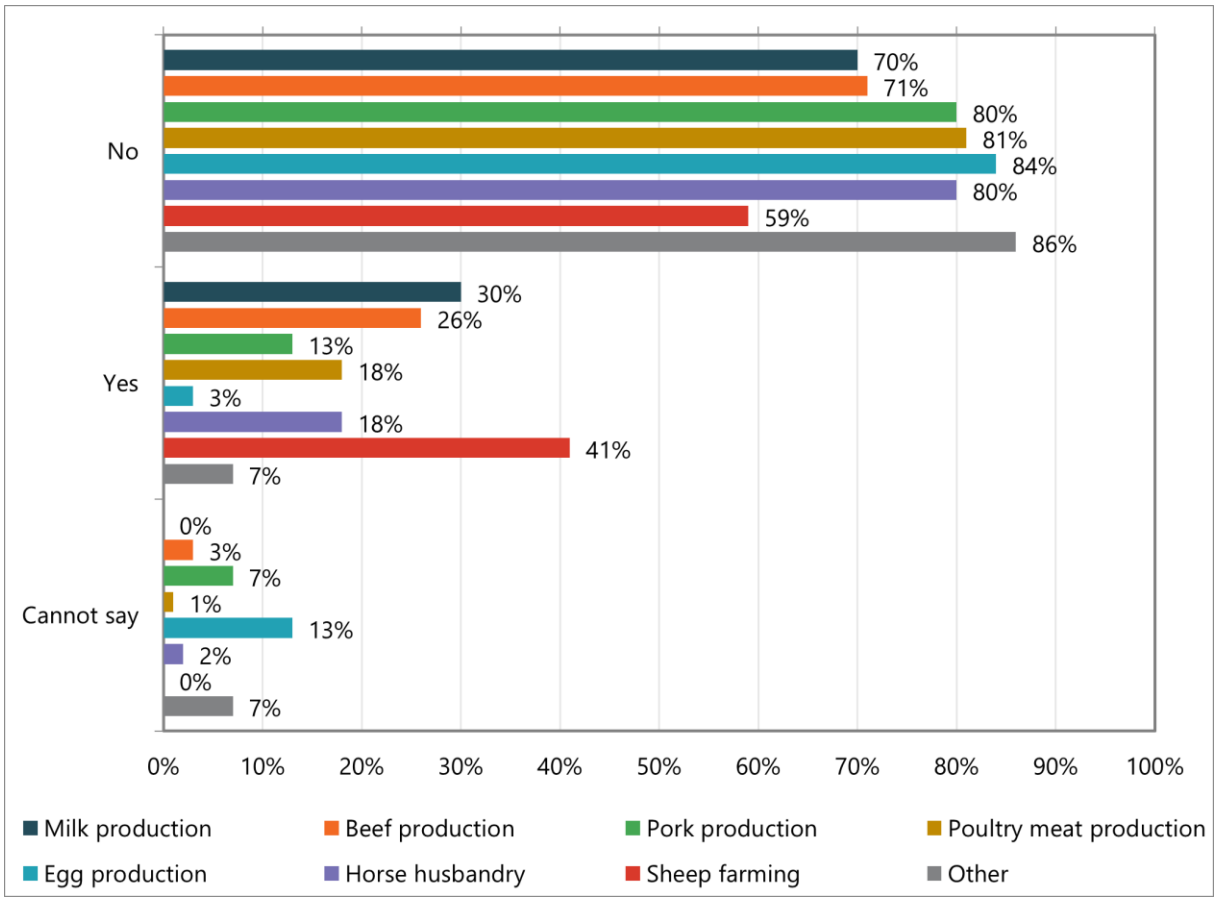


Figure 19. Quality problems identified in bedding materials during the last 12 months by main production.

Most respondents (66%) stated that there had not been any problems with the availability of bedding materials during the last 12 months. However, it should be noted that slightly less than a third of all respondents (31%) reported availability problems. Of all respondents, 3% could not say whether there had been any availability problems.

Most availability problems had been experienced on horse and cattle farms (Figure 20), and the fewest by pork and poultry meat producers. Egg producers' large percentage of the "I cannot say" option may be explained by the fact that few egg producers had used bedding materials.

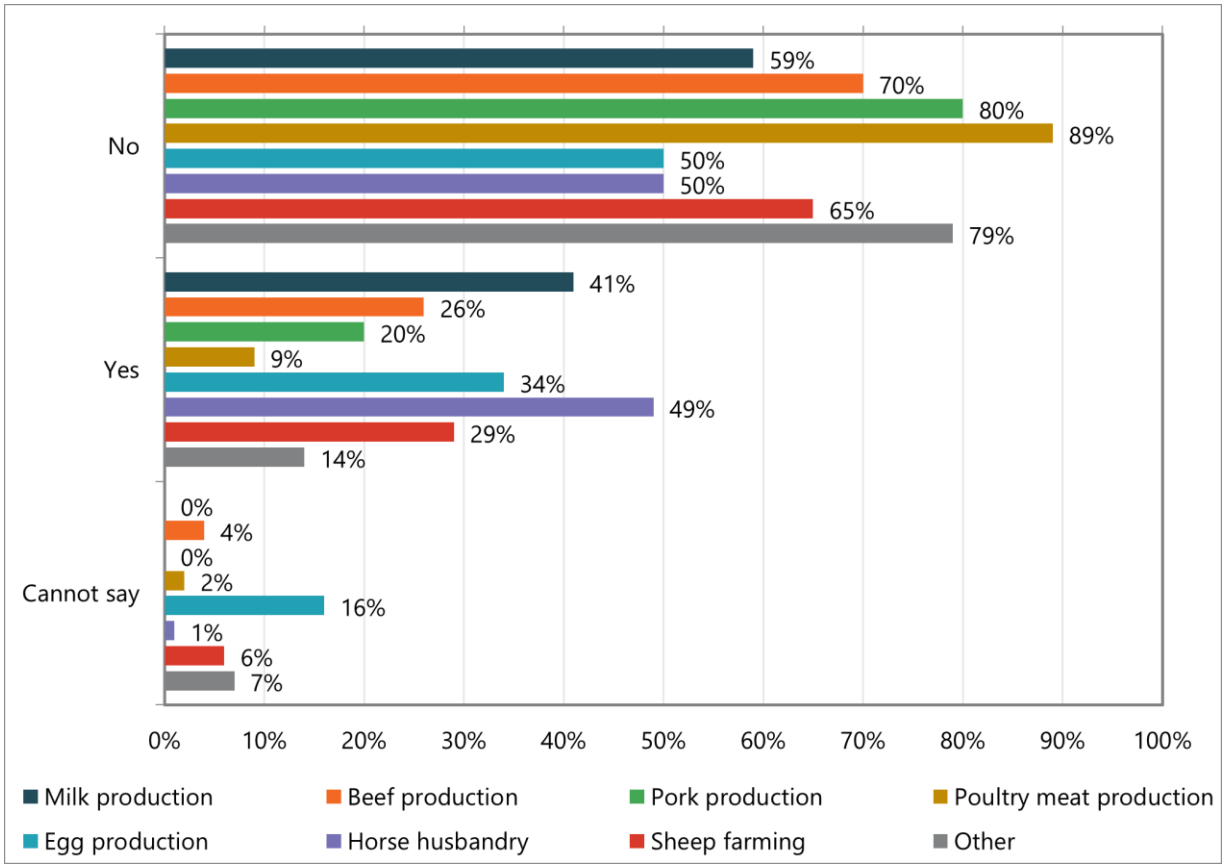


Figure 20. Availability problems identified in bedding materials during the last 12 months by main production.

Most availability problems were reported for wood shavings, sawdust and wood pellets. Delivery times had been long, it was difficult to obtain large batches, and prices had increased significantly. Many farms had also experienced problems with the availability of peat.

Regionally, availability problems mainly occurred in Northern Finland, where more than half of the respondents reported such problems (Figure 21). The fewest availability problems were reported by farms in Western Finland. Regional differences may result, at least for some materials, from the concentration of production and use in certain regions, as well as long transport distances.

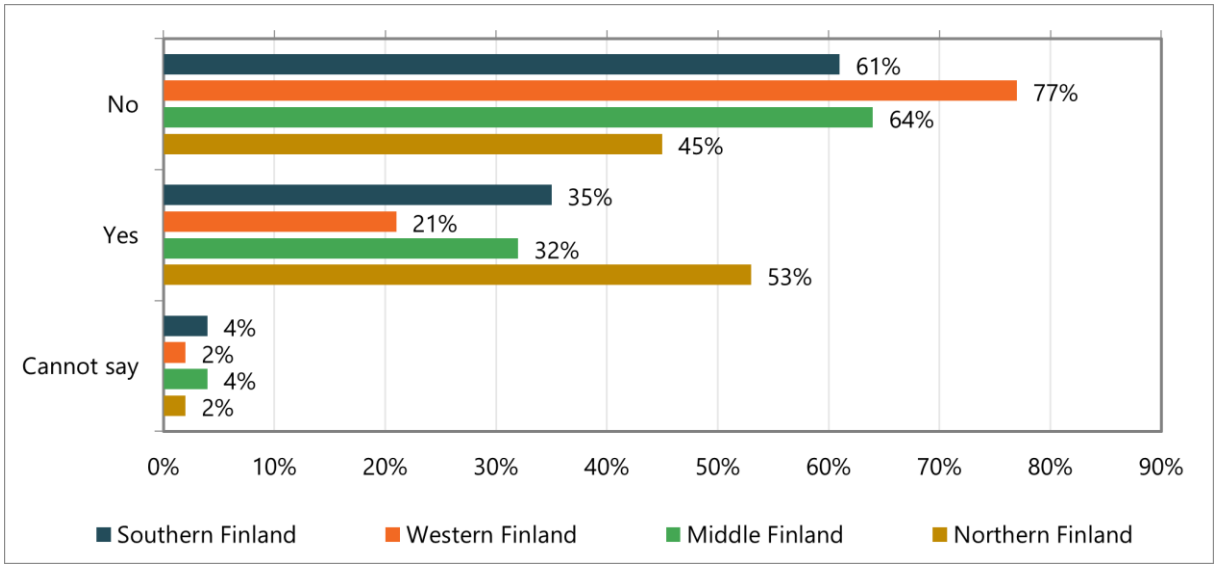


Figure 21. Availability problems identified in bedding materials during the last 12 months by major region.

11.7. Price of bedding materials and its impact on use

The respondents were asked whether the increase in the prices of bedding materials had affected the method and/or amount of using bedding materials or their selection. There was variation in the responses between main productions (Figure 22). Few pork and poultry meat producers stated that the price had had an effect, whereas the price increases had affected the use and selection of bedding materials in beef production and especially in horse husbandry. In sheep farming as well, more than a third of all respondents stated that the price increases had affected the use of bedding materials. Most frequently, the respondents reported changes in the use of peat, wood shavings and wood pellets. They were used in smaller amounts, and more attention was paid to cleaning to prevent any bedding materials being wasted. Some respondents had replaced their bedding material with straw or peat after the availability of wood-based materials had decreased, and their prices increased.

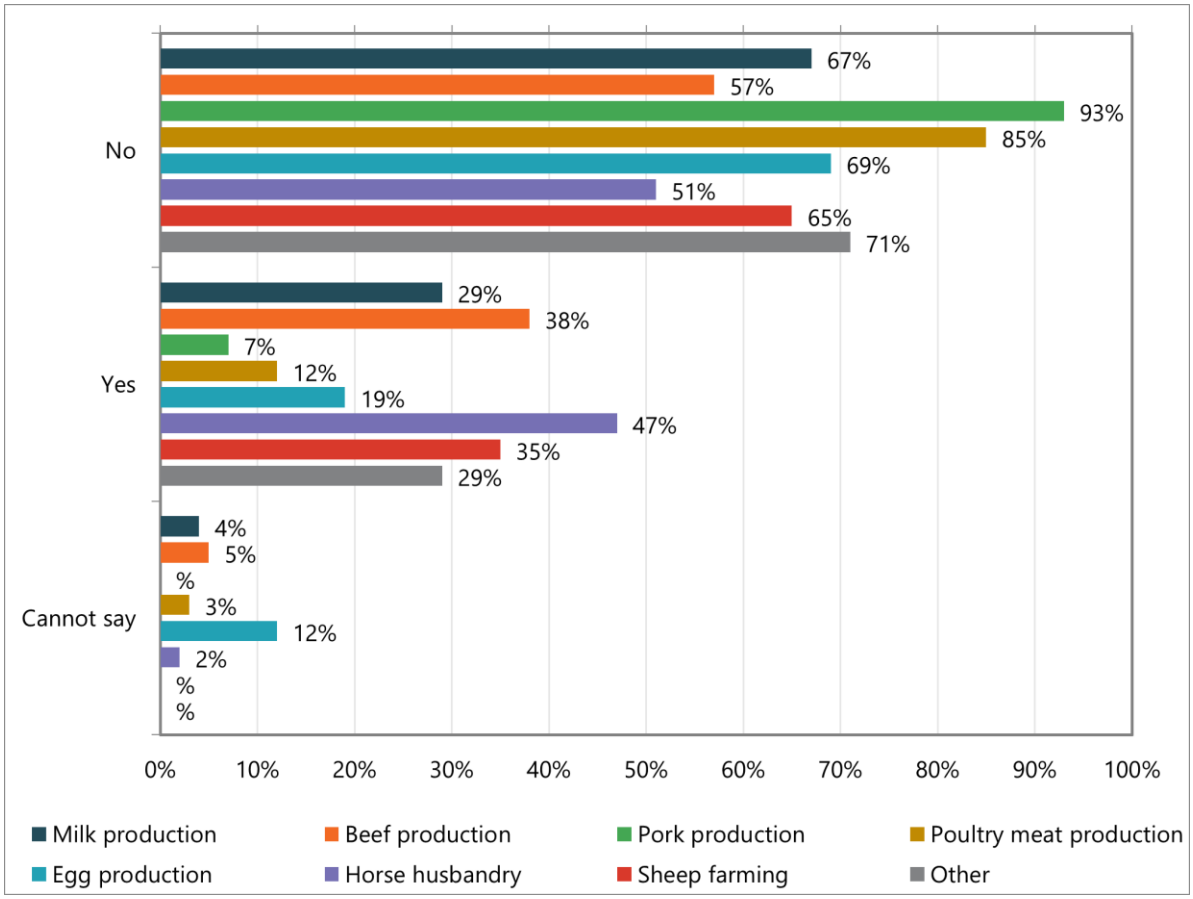


Figure 22. Impact of price increases on the use and selection of bedding materials.

Because most poultry meat farms use peat in bedding, and few optional bedding materials are available, this largely explains that the price increases have had no impact on the use or selection of bedding materials. In contrast, bedding materials are not used on many pork production farms, where they are mainly used as enrichment, which may explain that the price of bedding materials had no impact on the use and selection of bedding materials on most pig farms.

On horse and sheep farms, and especially in cattle production buildings with deep beddings, the use of bedding materials is necessary, and their amounts may be very significant, which may partly explain why the price of bedding materials had an impact on the use and/or selection of bedding materials on such farms. In addition, several bedding materials suitable for horses, cattle and sheep are available, which adds flexibility to bedding if the price and/or availability of bedding materials changes, for example.

A considerable number of all respondents in Northern Finland (slightly more than 20%) purchased peat in bales, and the difference with other regions was significant. The corresponding figure was 4% in Southern Finland, roughly 2% in Western Finland, and 7% in Middle Finland. One reason for the larger percentage of baled peat in Northern Finland may be related to transport costs. In bales, peat is packaged densely, allowing it to be transported in larger amounts than bulk material. One solid cubic metre of baled peat contains twice as much peat than when delivered as bulk material (Vapo 2023).

Tables 10–16 present the prices paid for different bedding materials in the spring of 2023 as reported by the respondents. The prices of all materials showed significant variation within

and between the major regions. The variation in the price of straw bales may partly be explained by a possible variation in the sizes of bales, depending on whether straw was in the form of small, round or square bales. In addition, some may have indicated EUR 0 as the price of self-produced and/or baled straw, in which case baling costs have not been taken into account. In contrast, some reported EUR 10–15 per bale as the price of baling when using an external contractor, and some indicated EUR 4 per bale as the price of self-baled straw. Many of the responses related to the price of straw had to be ignored because the unit had not been specified, i.e. whether the given number meant cubic metres, kilograms or pieces. Regionally speaking, average prices of all materials were highest in Northern Finland. However, no significant conclusions can be drawn from the prices, partly because the number of respondents was small in some questions, and partly because it was unclear how prices had been calculated for certain materials, including straw. The fact that some had reported prices with VAT and some with transport costs complicated the results' interpretation.

Table 10. Prices paid for peat in the spring of 2023 as reported by the respondents to the bedding material survey. Some prices included VAT and/or transport costs, which made it more difficult to compare the prices.

Major region	Average price per bulk cube, €/m³	Price fluctuation per bulk cube, €/m³	Average price per bale, €/m³	Price fluctuation per bale, €/m³
Southern Finland	17,8	4,0–35,0	59,0	53,3–72,1
Western Finland	14,2	4,0–22,0	76,7	66,7–86,7
Middle Finland	19,0	10,0–50,0	52,7	27,5–66,7
Northern Finland	23,0	15,0–60,0	48,0	28,0–66,0

Table 11. Prices paid for straw in the spring of 2023 as reported by the respondents to the bedding material survey.

Major region	Average price, cent/kg	Price fluctuation, cent/kg	Average price per bale, €/pcs	Price fluctuation per bale, €/pcs
Southern Finland	12	10–13	20,5	0,0–50,0
Western Finland	-	-	12,8	0,0–35,0
Middle Finland	13	0–13	13,2	0,0–35,0
Northern Finland	0	-	21,6	0–70,0

Table 12. Prices paid for wood shavings in the spring of 2023 as reported by the respondents to the bedding material survey.

Major region	Average price per bulk cube, €/m³	Price fluctuation per bulk cube, €/m³	Average price per bale, €/pcs	Price fluctuation per bale, €/pcs
Southern Finland	9,8	5,0–15,0	10,3	5,8–27,0
Western Finland	14,6	9,0–23,0	9,0	5,4–14,0
Middle Finland	9,1	4,5–15,0	7,5	4,5–12,0
Northern Finland	17,3	5,0–49,0	8,8	6,1–11,9

Table 13. Prices paid for sawdust in the spring of 2023 as reported by the respondents to the bedding material survey.

Major region	Average price per bulk cube, €/m³	Price fluctuation per bulk cube, €/m³	Average price per bale, €/pcs	Price fluctuation per bale, €/pcs
Southern Finland	13,0	10,0–16,0	-	-
Western Finland	-	-	-	-
Middle Finland	0,6	0–1,2	9,4	8,0–10,7
Northern Finland	13,3	10,0–15,0	-	-

Table 14. Prices paid for wood pellets in the spring of 2023 as reported by the respondents to the bedding material survey.

Major region	Average price, €/ton	Price fluctuation, €/ton
Southern Finland	391	240–900
Western Finland	345	320–370
Middle Finland	390	340–440
Northern Finland	403	370–440

Table 15. Prices paid for straw pellets in the spring of 2023 as reported by the respondents to the bedding material survey.

Major region	Average price, €/ton	Price fluctuation, €/ton
Southern Finland	922	139–4 000
Western Finland	-	-
Middle Finland	-	-
Northern Finland	1 270	540–2 000

Table 16. Prices paid for reed canary grass bales in the spring of 2023 as reported by the respondents to the bedding material survey.

Major region	Average price, €/pcs	Price fluctuation, €/pcs
Southern Finland	-	-
Western Finland	-	-
Middle Finland	16	10–22
Northern Finland	-	-

11.7.1. Willingness to test bedding materials

The survey identified the respondents' willingness to test bedding materials by asking whether they had considered any bedding materials they had not previously used. Significantly more than half the respondents (62%) stated that they had not considered new bedding materials. Yet it was also noteworthy that almost a third of all respondents (29%) had considered testing new bedding materials. The most common reasons for testing or considering new materials included the price and/or availability of current materials. Of all respondents, 9% were unable to say anything about their willingness to test new bedding materials.

The respondents were also asked what new bedding materials they had considered. Testing peat was considered most (12% of all respondents). It was followed by straw and hemp (10% and 9% respectively). Testing straw pellets, separated manure, wood shavings, and reed canary grass was considered by 7–8% of all respondents. A few respondents mentioned pellets, sand and sawdust in general, while individual respondents listed chips, ground common reed, newspapers, flax and sunflower pellets.

There were certain significant differences in considering new bedding materials between main productions (Figure 23). Different extremes were represented by poultry and horse husbandry, with their responses differing from other main productions. Only one in every ten poultry meat producers had considered testing new bedding materials, whereas nearly half the respondents had considered new materials in horse husbandry. Furthermore, only one in every six egg producers had considered new materials, whereas a third of all respondents had considered them in other main productions. In milk production, separated manure was significantly the most popular alternative for current bedding materials. One in three respondents mentioned it as a potential new option. The use of sand as a bedding material attracted milk producers in particular, as almost a fifth of all respondents stated that they would be interested in testing it. Among beef producers, the most popular option was reed canary grass, with almost a fifth of all respondents having considered it. In poultry meat production, the most frequently mentioned alternatives were wood shavings and straw, both of which were mentioned by a quarter of respondents. There were no significant differences between new bedding materials in egg production. All the alternatives mentioned were stem materials: straw; reed canary grass; and hemp. In horse husbandry, some had already tested various options. The most popular new bedding materials included hemp, peat and straw pellets, which were mentioned in a fifth of all responses. In addition, slightly more than a tenth of all respondents mentioned straw and pellets in general as attractive new options. In sheep farming, reed canary grass was significantly the most used new bedding material. It was mentioned by all the respondents who had considered new options.

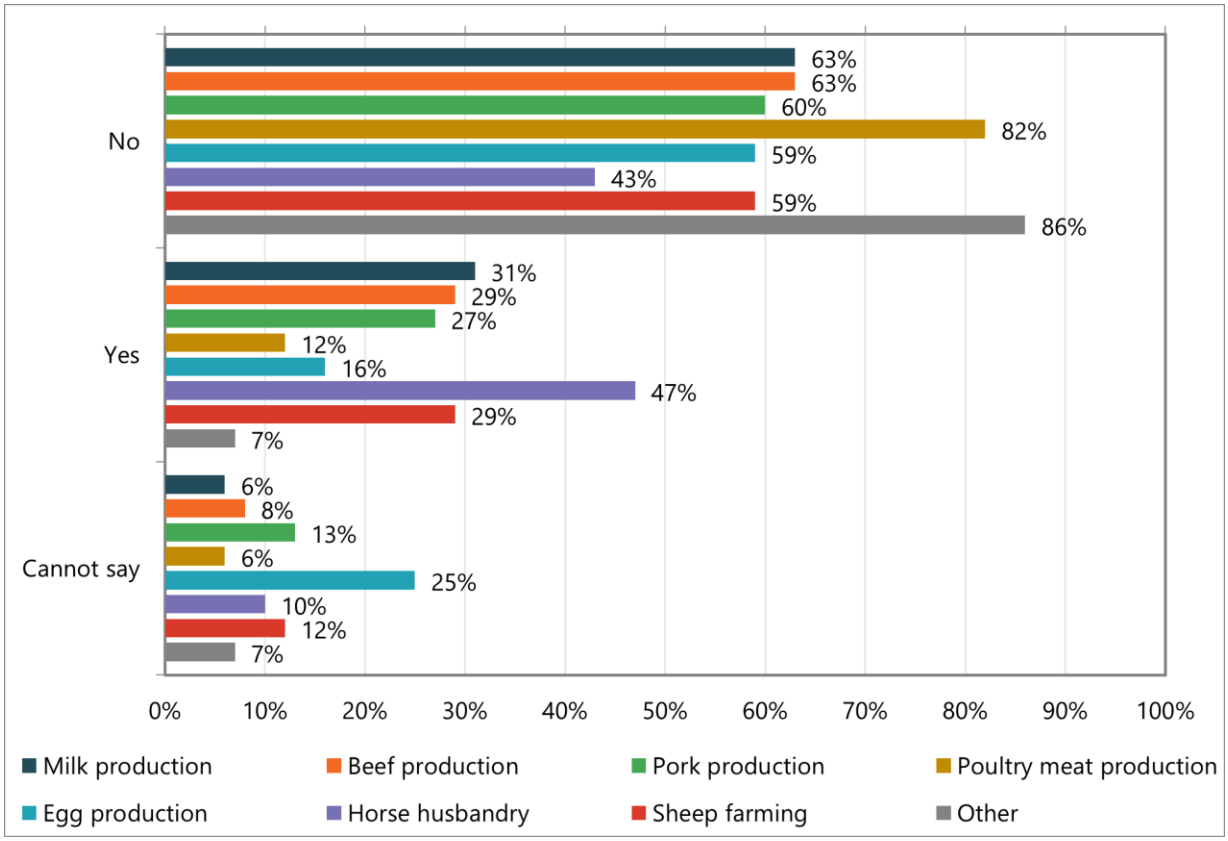


Figure 23. Willingness to test new bedding materials that had not previously been used by main production.

11.8. Procurement channels of bedding materials

When asked about the primary procurement channels of bedding materials, the respondents were able to select multiple options. Nearly half the respondents acquired bedding materials directly from their producers (Figure 24). The results were the same when examined by main production and region, with the exception of egg production and Northern Finland, where slightly more respondents mainly acquired bedding materials through agricultural, hardware or discount stores (Figures 25 and 26). Direct procurement from farms that produce bedding materials was another significant procurement channel, as nearly a fifth of all respondents reported that they produced bedding materials on their farm, and 15% purchased bedding materials from a partner farm. Examined regionally, bedding material production on farms is a significant procurement channel in the major region of Middle Finland in particular. Regarding main productions, the significance of bedding materials produced on farms was emphasised on cattle and sheep farms. The bedding material affects procurement channels, which is also partly reflected in the distribution of procurement channels by main production. Straw and reed canary grass are mainly produced on the farm on which they are also used or purchased from a partner farm. In contrast, straw pellets and hemp are always purchased from agricultural, hardware or discount stores. Poultry meat producers nearly exclusively acquire bedding materials from companies that produce it. Straw, peat, wood shavings, sawdust and wood pellets were acquired directly from companies that produced bedding materials.

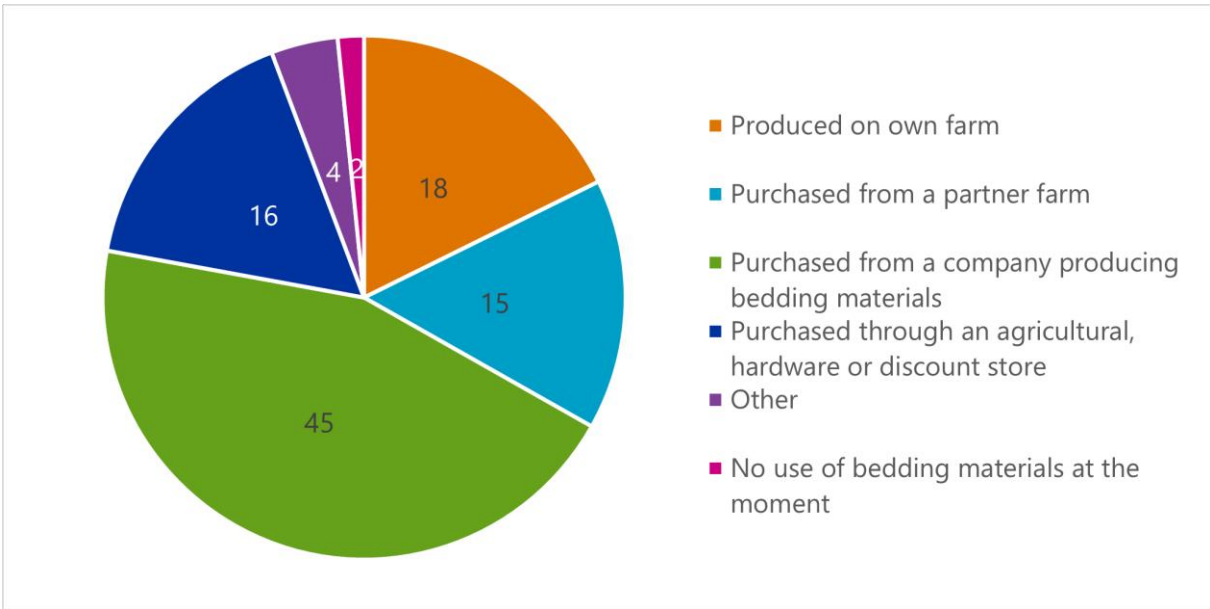


Figure 24. Procurement channels of bedding materials and their percentage.

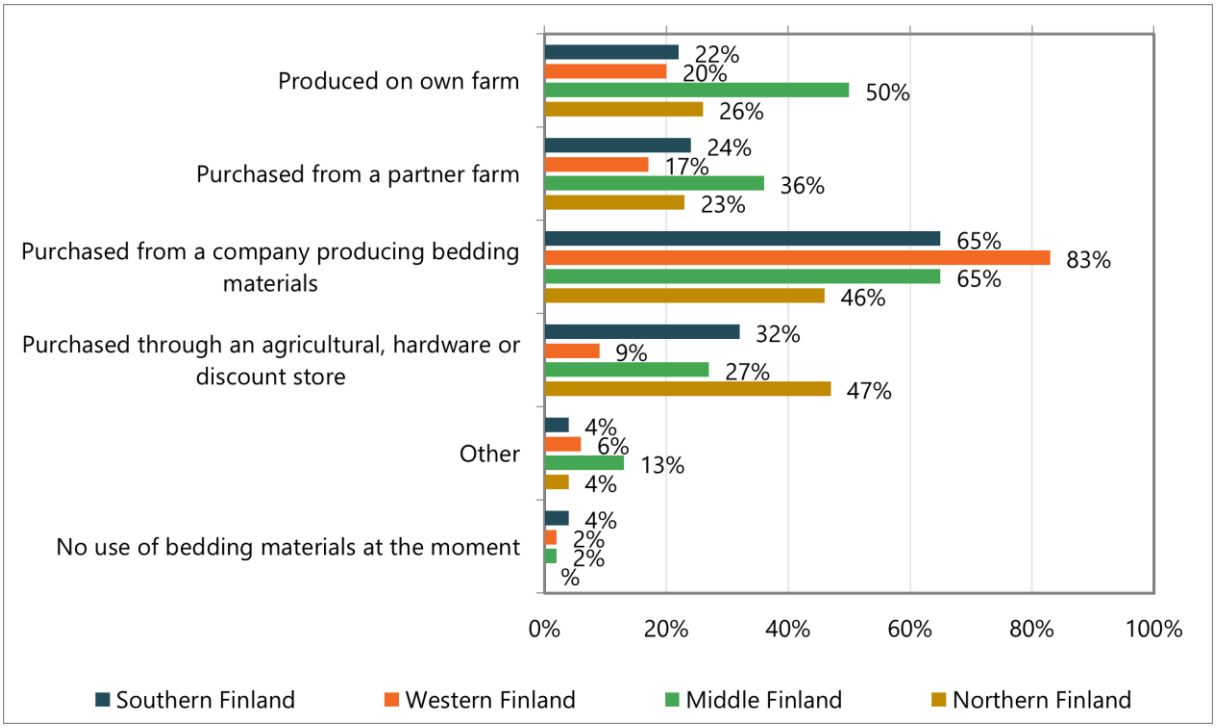


Figure 25. Primary procurement channels of bedding materials by major region.

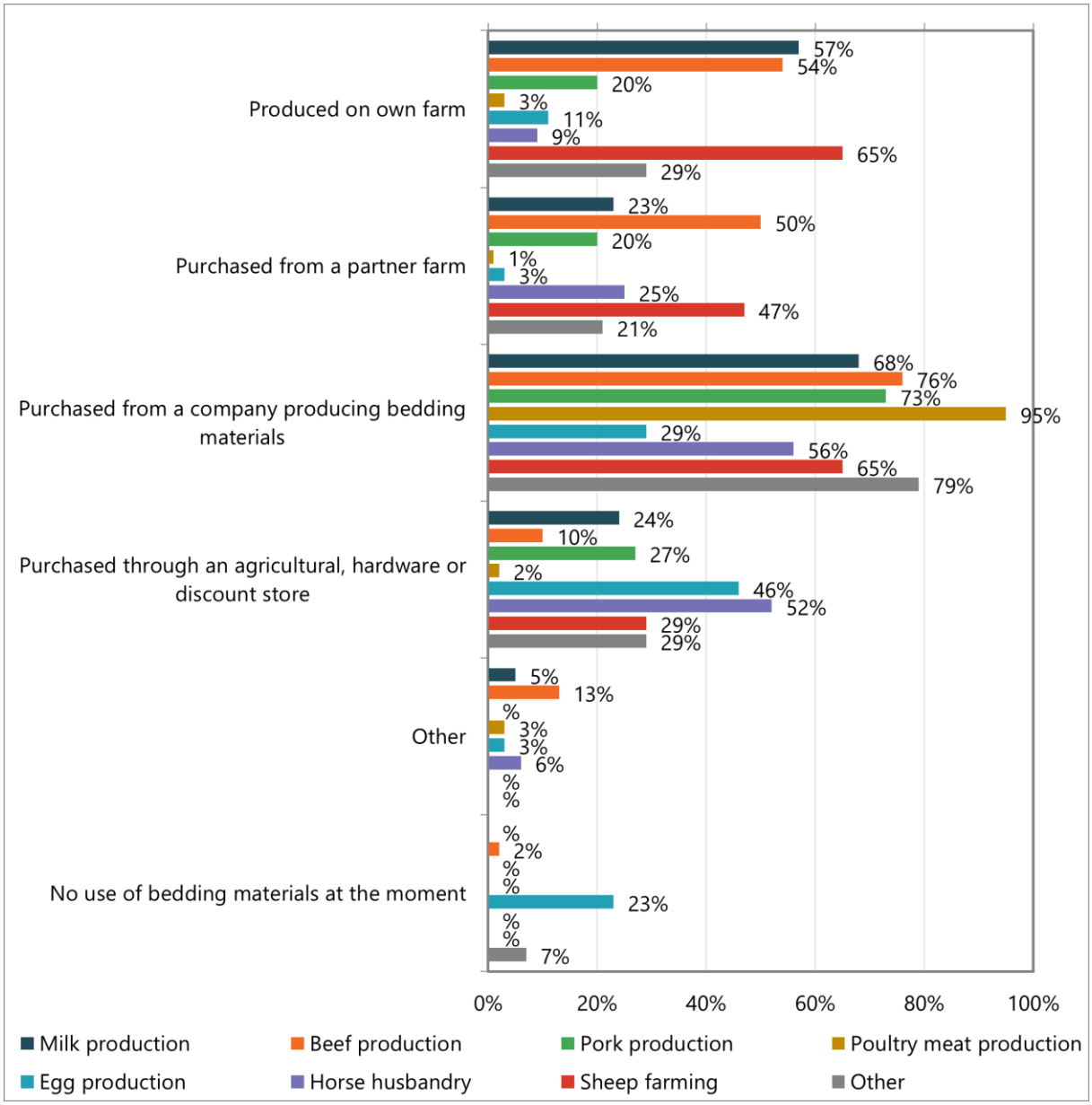


Figure 26. Primary procurement channels of bedding materials by main production.

11.9. Further use of manure

When asked about the further use of manure, the respondents were able to select one or several of the options given. More than half the respondents spread manure directly on their fields, and slightly more than a quarter used it as a fertiliser on the fields of their partner farms (Figure 27). Slightly more than a tenth mentioned composting before fertilisation. The use of manure as a raw material for biogas was uncommon, as only 1% of all respondents stated that manure was used in biogas production.

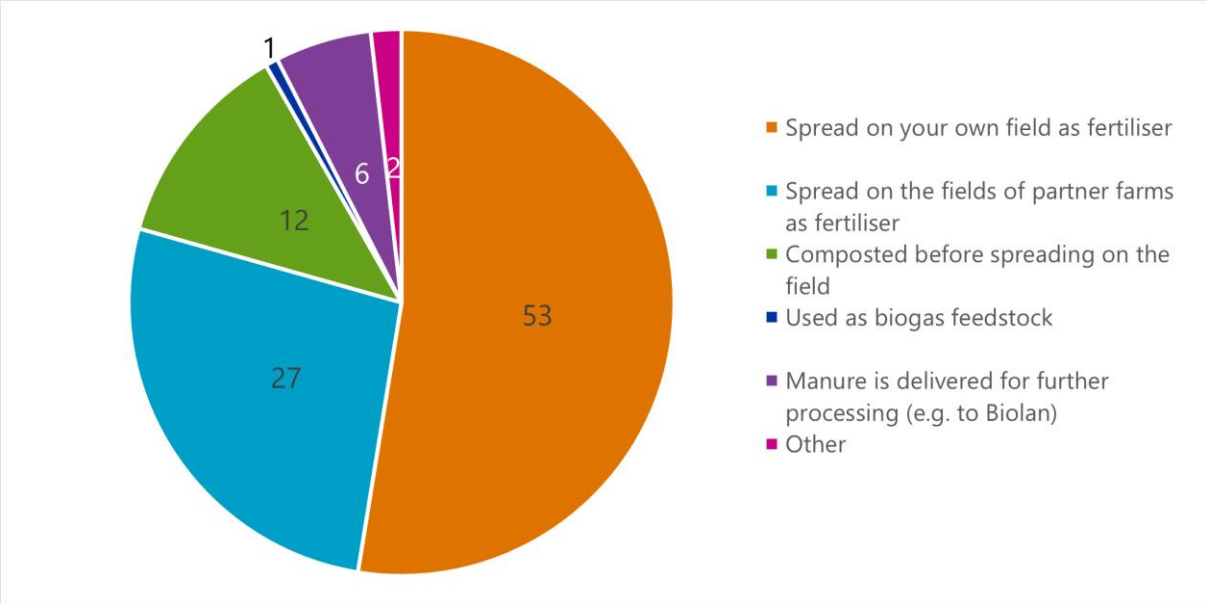


Figure 27. Further uses of manure.

The further processing of manure showed some regional differences. Spreading manure on the farm's fields was the most common option in all regions, while its use on the fields of partner farms was more common in Southern and Western Finland than in Middle and Northern Finland (Figure 28). Delivering manure for further processing appeared to be significantly more common in Western Finland than in the other regions. This can partly be explained by the concentration of poultry meat production in the region of Western Finland and by the fact that a considerable proportion of poultry manure is delivered for further processing (Figure 29).

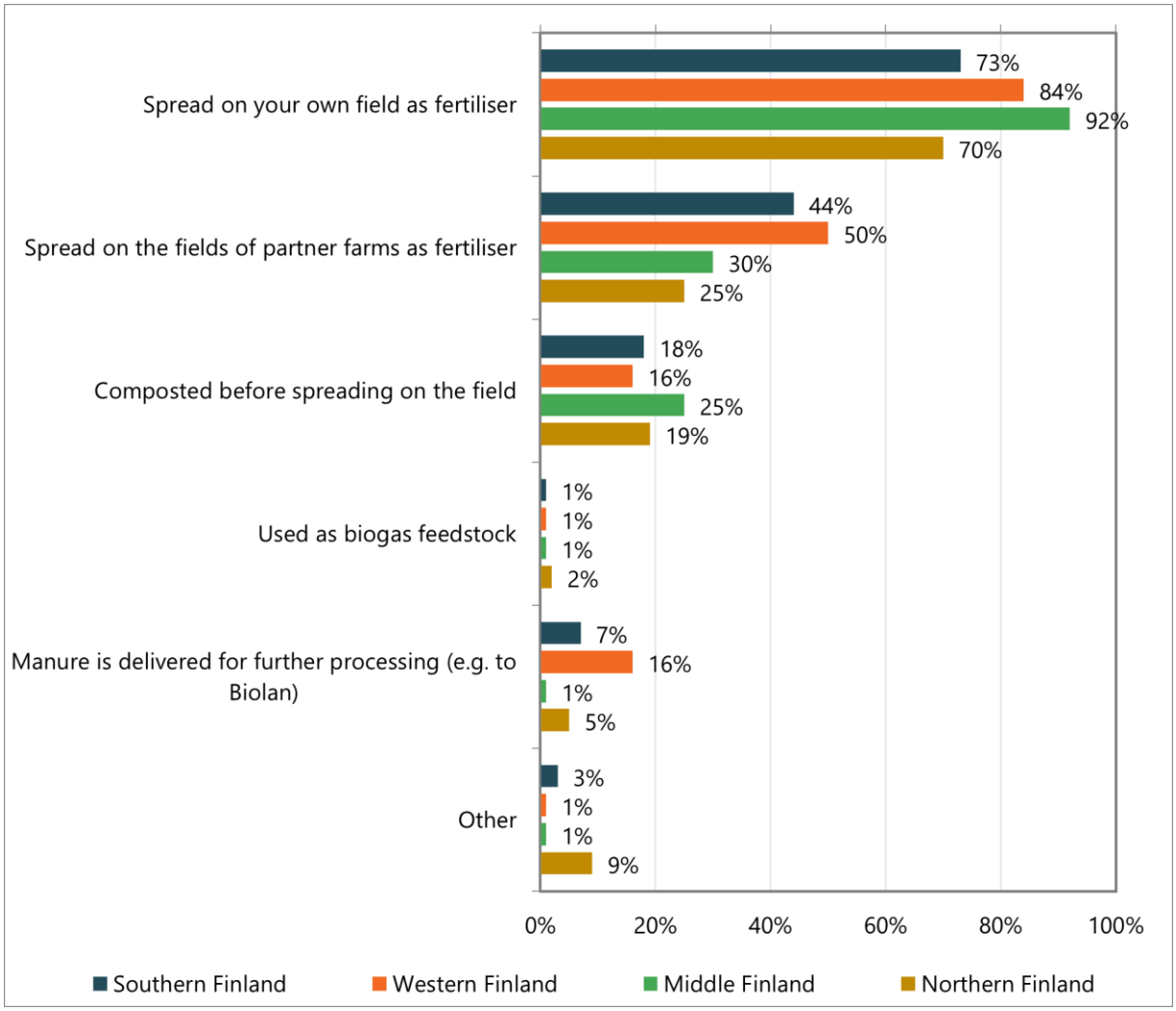


Figure 28. Further uses of manure by major region.

There were also differences between main productions in the further use of manure (Figure 29). Horse husbandry stands out in that only half of all horse farms spread manure on their fields. On many farms, this option is limited by not having any fields. Almost half of the horse farms use the fields of the partner farms for manure spreading. Horse manure is also delivered for spreading on fields on crop production farms. More than half the poultry meat producers also use partner farms in addition to their own fields. In addition, almost a third of all poultry meat producers deliver manure for further processing. Composting before spreading on fields is used most frequently in horse and sheep farming, in each of which a third of all respondents stated that they composted manure before using it. More pork producers than the average responded that manure was used as a raw material for biogas. On horse farms, the sale or transfer of manure directly to consumers for use as a fertiliser in home gardens was also relatively common ("Other" option).

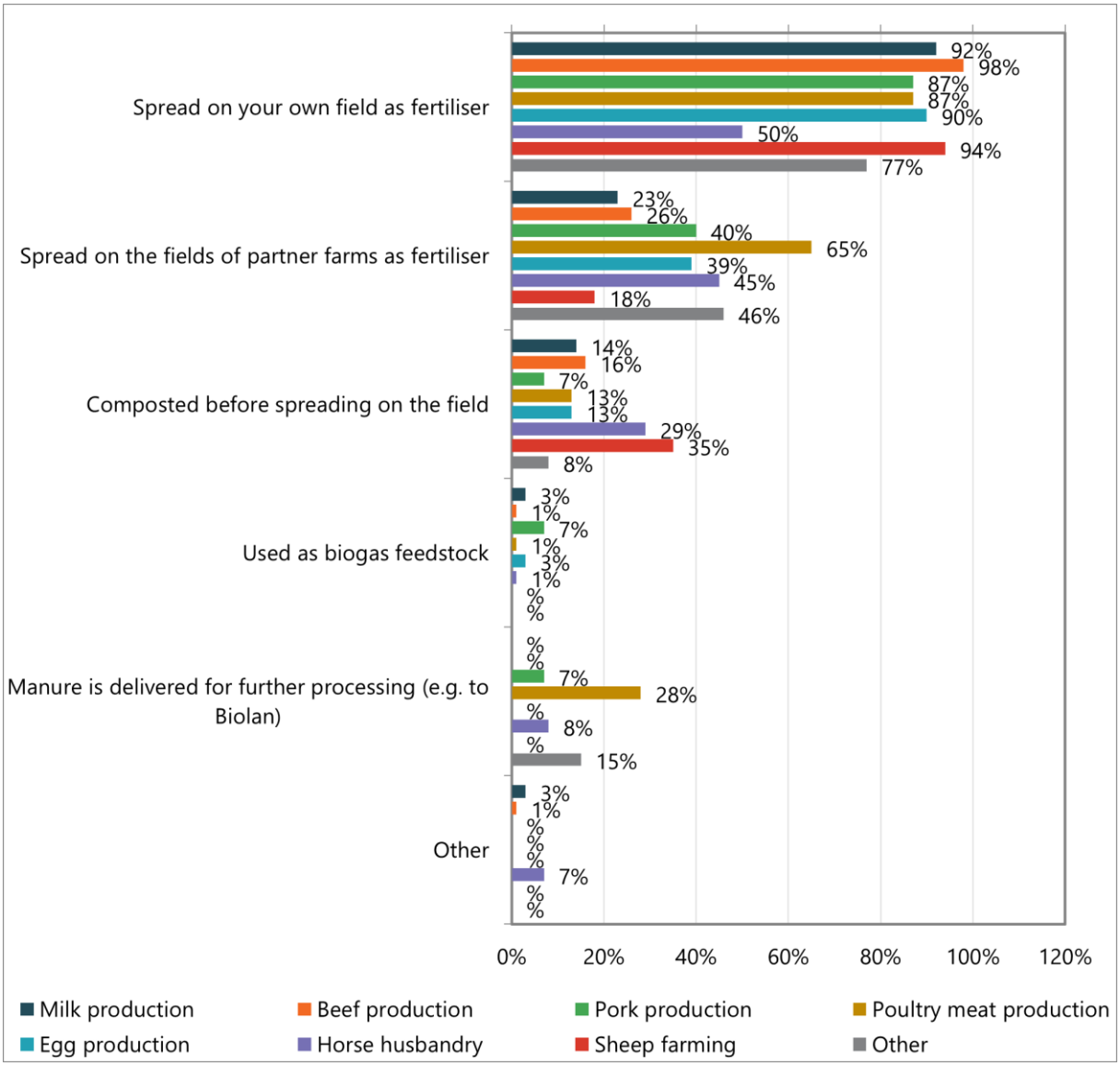


Figure 29. Further uses of manure by main production.

11.10. Near-future outlook for bedding material markets

When asked about the near future of the bedding material markets, especially regarding the availability of bedding materials and the development of prices, the responses focused on challenges and fears arising from concerns about higher costs and the decreased availability of bedding materials.

Regarding availability difficulties, fiercer competition for bedding materials and wood-based materials in particular was raised. The availability of peat was expected to decrease in many responses, revealing major concerns about how to replace it. A potential decrease in the quality of peat was also mentioned. Some respondents had contractual peat producers who had promised that there would be enough peat for years to come. Other concerns included the discontinuation of crop production in certain areas, which was reflected in the availability of plant stem materials, and straw in particular. The pricing of straw also raised concerns if it had to be purchased. Regional differences were expected to increase.

Some responses predicted that the use of separated manure would increase. One response stated that there would be no problems with the use of sand as a bedding material. Domestic hemp was requested, and some responses showed interest in reed canary grass.

Some responses also showed a positive approach and faith in the markets returning to normal.

The profitability crisis in food production raised general concerns. Some respondents considered whether they would be able to continue production any longer if the availability of bedding materials decreased, and prices increased.

Animal welfare and the significance of bedding materials as part of it were also mentioned. If farms can no longer afford sufficient bedding, or sufficient amounts of bedding materials cannot be obtained, the fear is that animal welfare will suffer. Regarding peat, it was mentioned separately that "*peat is the antibiotic of Finnish livestock farming*". In a significant number of responses, peat was mentioned as a bedding material that had no replacement. It was also stated that its availability as a bedding material must be ensured in the future. The responses showed criticism of Finland's peat policy and especially of the lack of understanding that peat's use in heat production should be considered separately from its use as a bedding material and in crop production.

12. Business survey on the production of and demand for bedding materials other than peat

In the spring of 2023, Luke conducted a bedding material market survey targeted at all companies that produced, sold and/or imported bedding materials. It was conducted as a Webropol survey between 23 May and 4 June 2023. Its primary goal was to identify the availability of and demand for bedding materials other than peat. Bedding peat was omitted from the business survey because exhaustive information about its production volumes and near future development outlook had already been obtained before the survey (see Section 6).Description of the responding companies

A response link to the survey was sent personally by email. A total of 94 potential respondents was contacted, of whom 20 responded. The response rate was therefore 21%. Based on the major regions, nearly half the responding companies stated that their company's head office was in Southern Finland, while slightly more than a third had their head office in Middle Finland (Figure 30). Of the responding companies, 79% were engaged in the production, sale and/or importing of bedding materials at the time of responding.

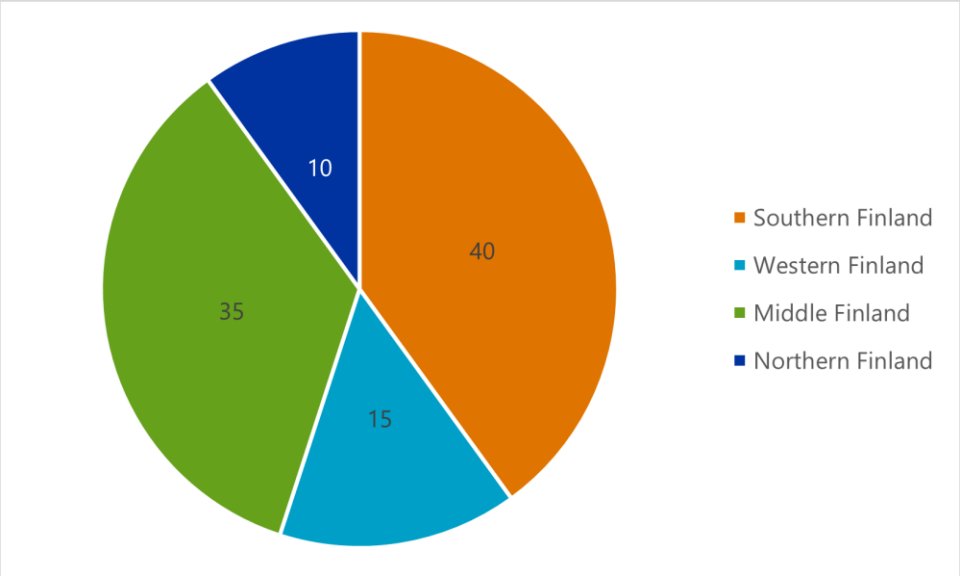


Figure 30. Location of the head office of the companies that responded to the survey by major region.

As the responding companies were potentially also engaged in other business operations, the respondents were asked about the form of their operations regarding bedding materials. The respondents were able to select one or more options. The most common forms of operations included the production and sale of bedding materials directly for users or retailers. Roughly a sixth of all respondents stated that they imported and sold bedding materials directly to users (Figure 31). A quarter selected the "Other, please specify" option. Such other forms included sales for fuel, distribution to retailers and private label operations.

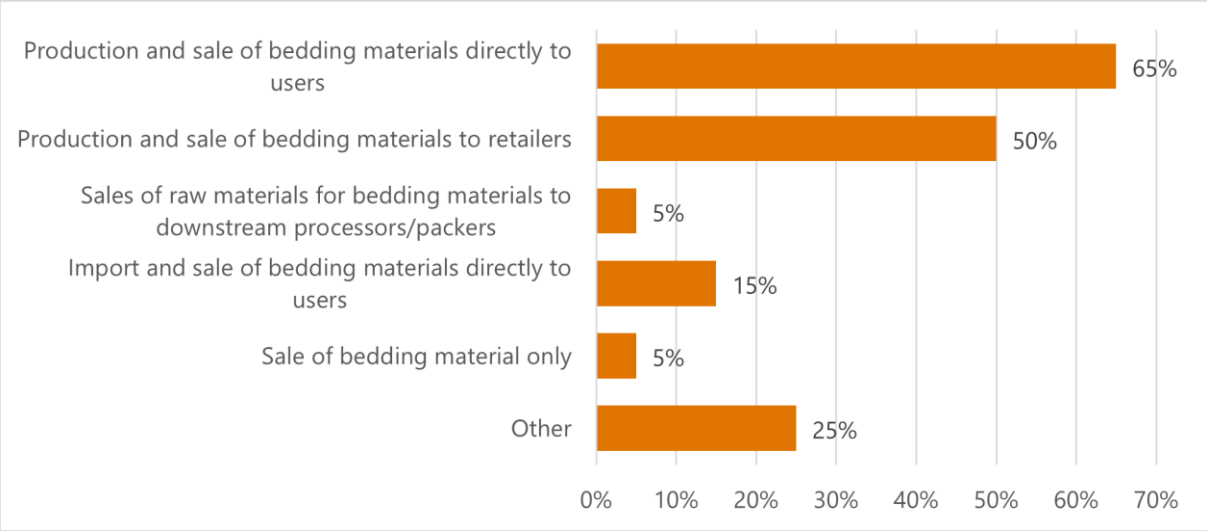


Figure 31. Business form of the responding companies regarding bedding materials.

The responding companies were asked about the size of their delivery area, i.e. in which major regions they delivered bedding materials. The respondents were able to select one or more option. Three out of four companies delivered bedding materials in Southern Finland, and more than half in Northern Finland (Figure 32). A fifth of the companies also delivered bedding materials to the Åland Islands.

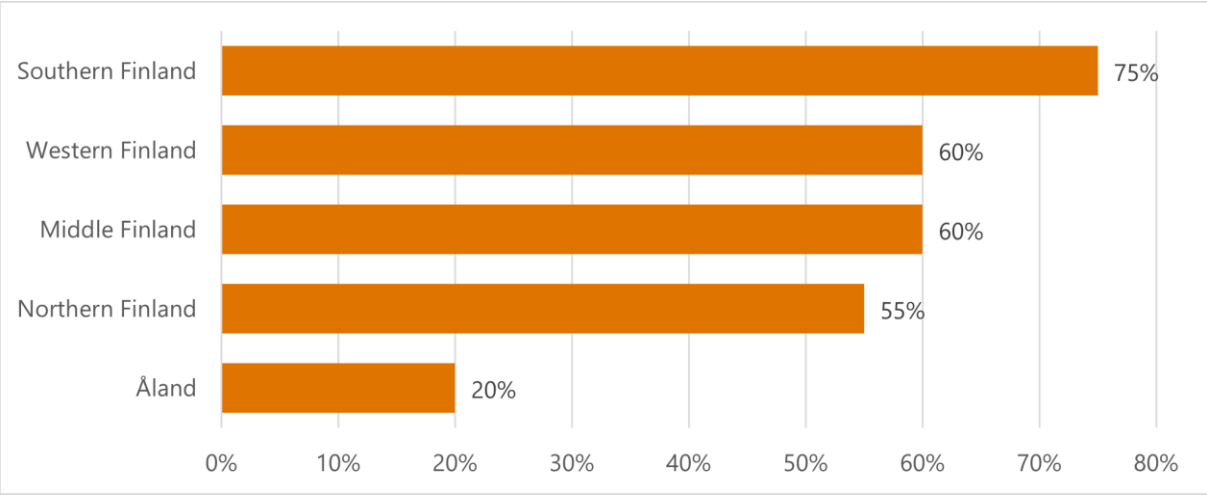


Figure 32. The major regions in which the responding companies delivered bedding materials.

12.1. Customers of the responding companies

The respondents were asked to name the key customer groups to which they delivered bedding materials. The respondents were able to select one or more options. Horse farms were the key customer group for three out of four respondents, and milk and beef producers for 60% (Figure 33). A fifth of the respondents mentioned pork producers and poultry farms as their key customer groups. Other customer groups in addition to livestock farms and stables included incineration plants and the pellet industry ("Other"). The small role of sheep farms can partly be explained by the use of straw as the primary bedding material in sheep farming.

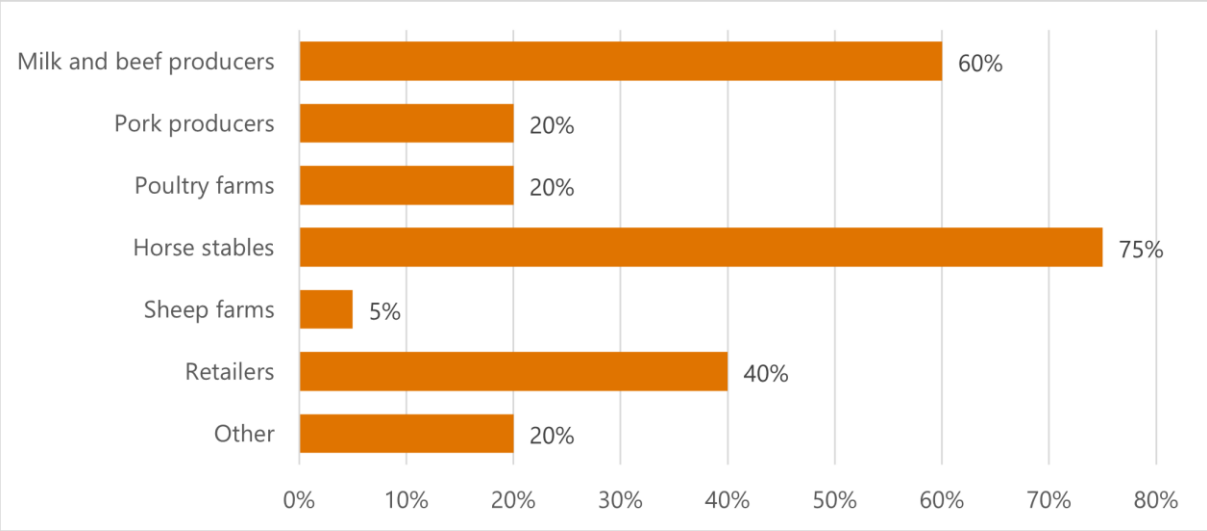


Figure 33. Key customer groups of the responding companies.

12.2. Bedding materials produced, imported and sold by the companies

The respondents were asked to provide information about the bedding material range of the companies they represented. They were able to select one or more bedding materials and/or write down their response under the open-ended question. The most common materials included wood-based materials, including wood shavings, sawdust and wood pellets (Figure 34). They were followed by plant stem materials, including straw pellets, shredded and pelleted reed canary grass, and hemp.

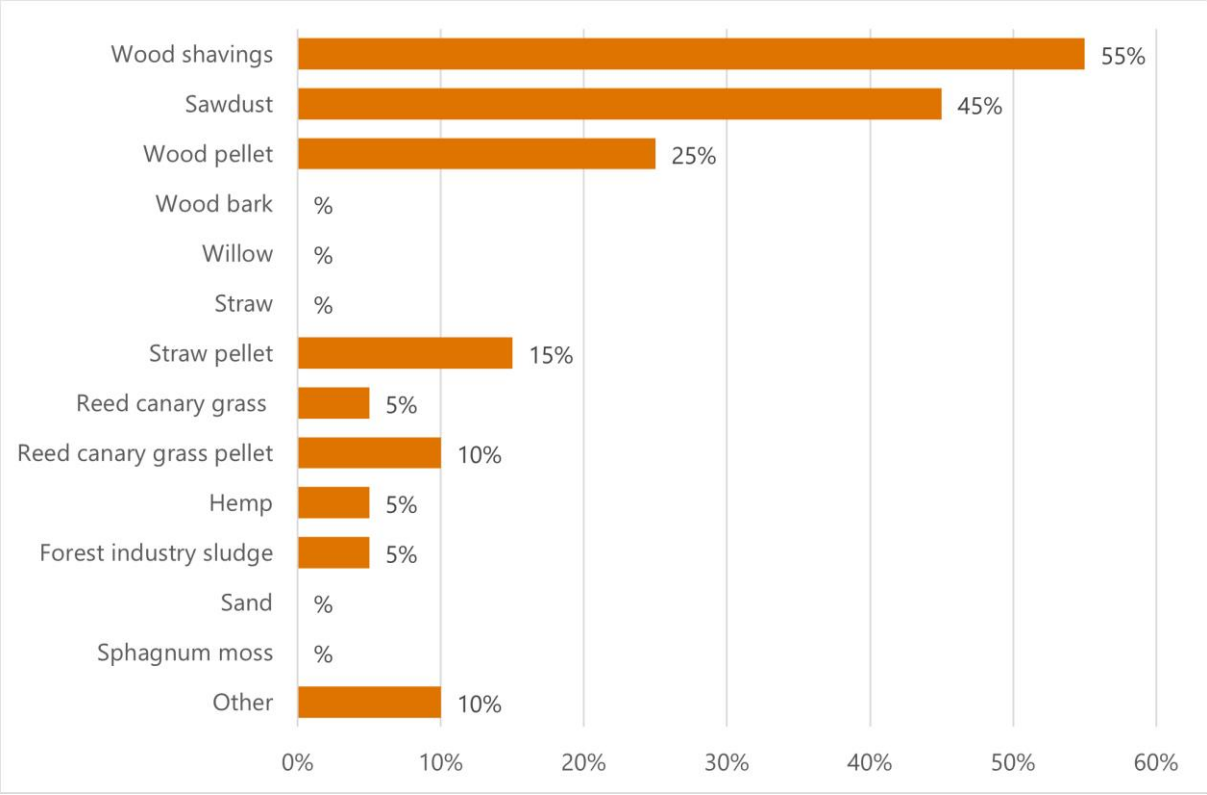


Figure 34. Bedding materials produced, imported and sold by the responding companies.

In the context of bedding materials, the respondents were asked about the origin of bedding materials and/or their raw materials. There were differences in the domestic origin between bedding materials (Figure 35). Of wood-based materials, sawdust was 100% domestic, and wood shavings and wood pellets were 80–90% domestic. Three quarters of all reed canary grass produced was of domestic origin, while all reed canary grass pellets came from Finland. Straw pellets and hemp were completely imported. Wood shavings and wood pellets came from Ukraine, straw pellets from Latvia and Lithuania, reed canary grass from Lithuania, and hemp from the Netherlands. Domestic bedding materials and their raw materials came from various parts of Finland. Half came from Middle Finland, 40% from Southern and Western Finland, and 35% from the region of Northern Finland.

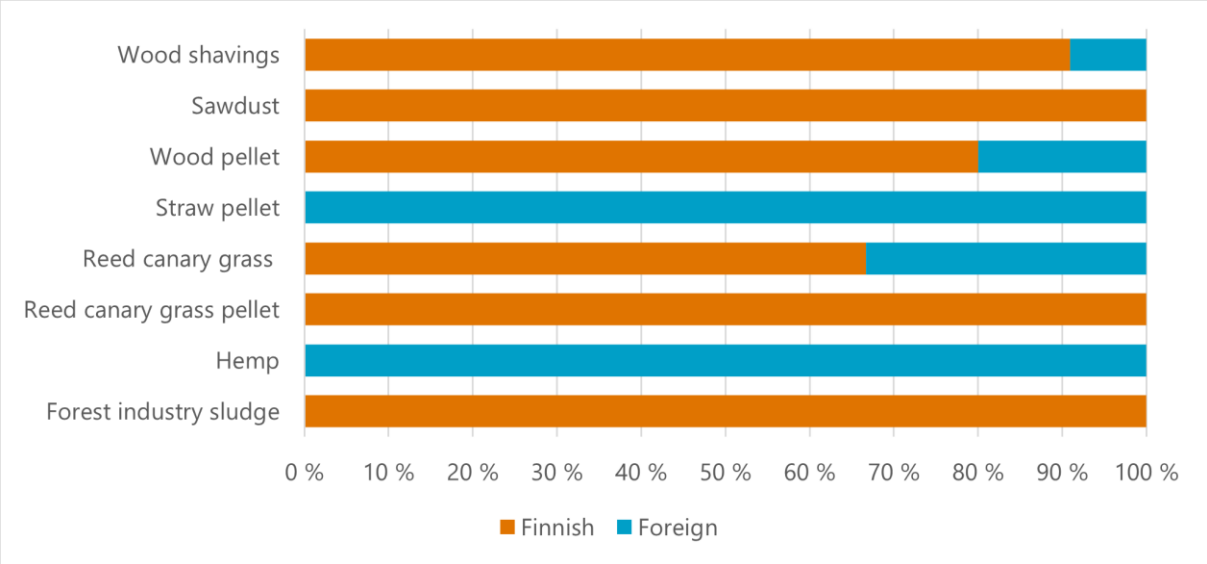


Figure 35. Origin of bedding materials. Domestic material is highlighted in orange, and foreign material in blue.

12.3. Production and sales volumes of bedding materials

The respondents were asked about the annual production and sales volumes of the bedding materials they produced and/or sell. Table 18 presents production and sales volumes regarding the bedding materials that had two or more respondents.

Table 17. Amounts of bedding materials produced and sold annually by the responding companies (m^3 or tonnes per producer).

Bedding material	Annual production volume, m^3 or ton/producer	Annual sales volume, m^3 or ton/producer
Wood shavings[1]	23 560 m^3	14 060 m^3
Sawdust[2]	227 620 m^3	2 740 m^3
Wood pellet	-	100 ton
Straw pellet	-	1 000 ton
Reed canary grass pellet[3]	260 ton	440 ton

[1)] Some figures converted; cubic weight used in the calculation: 100 kg/m^3.
[2)] Some figures converted; cubic weight used in the calculation: 150 kg/m^3.
[3)] Some figures converted; cubic weight used in the calculation: 600 kg/m^3.

12.4. Processing and delivery

The survey identified the processing of the bedding materials produced, imported and/or sold by the responding companies and their delivery to customers. The respondents were able to select one or more option. The most common processing methods included packaging (half the respondents) and pelleting (almost half) (Figure 36). They were followed by drying (a third) and dust removal and fine matter screening (a quarter). The least common option was the production of mixtures (one respondent only).

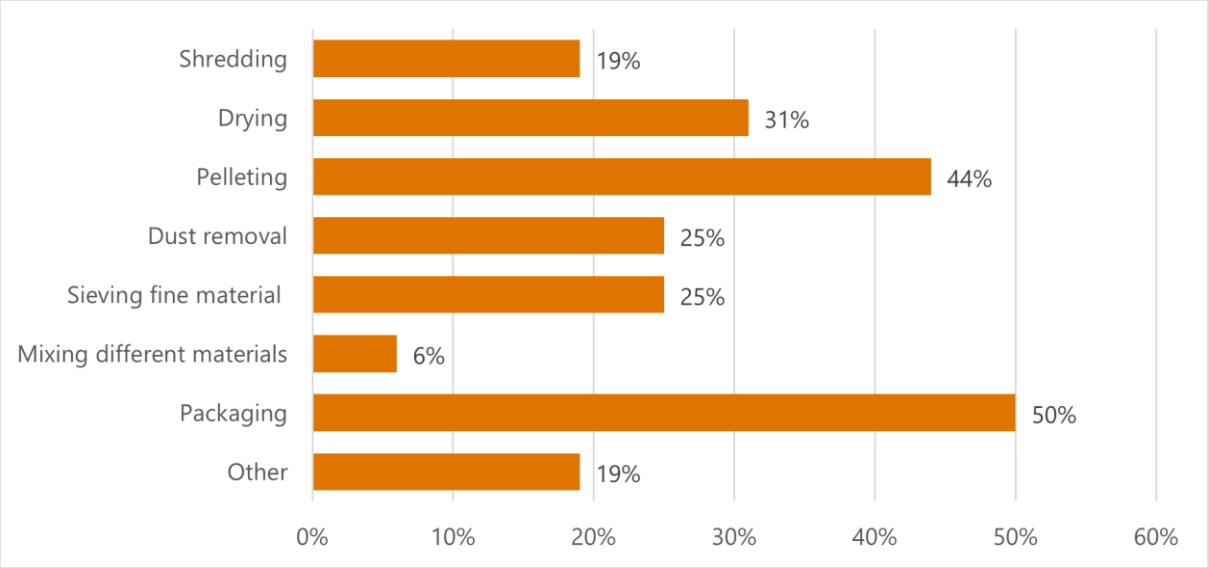


Figure 36. Processing of bedding materials by responding companies.

The most common delivery method was the delivery of bulk material (Figure 37). It was followed by various sizes of sacks and packaging in plastic. Wood shavings and sawdust were delivered as bulk material, whereas other materials were delivered packaged. Wood shavings and sawdust were also delivered packaged in plastic, and wood shavings were also available in small sacks. Bulk bags were mainly used for pellets.

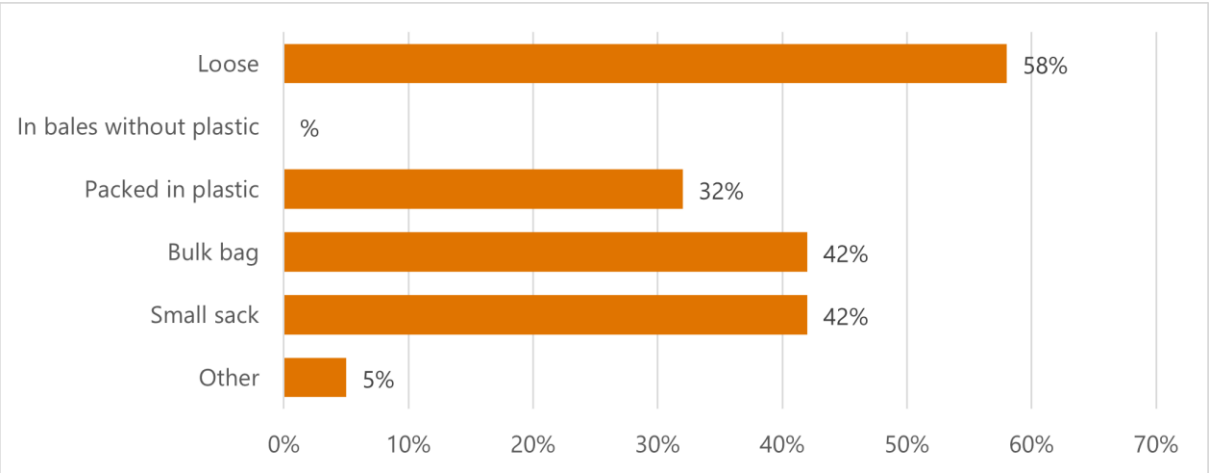


Figure 37. Delivery of bedding materials by responding companies.

12.5. Quality and availability problems

The responding companies were asked about any quality and availability problems associated with bedding materials and/or their raw materials. Roughly a fifth of all respondents (21%) had had quality problems during the last 12 months. The problems were nearly exclusively related to moisture and dust. More than half the respondents (51%) had had availability problems. They were mainly related to wood shavings, while there had also been challenges in the availability of reed canary grass and various pellets.

12.6. Price changes and the impact of changes in bedding material markets on production and demand

The survey aimed to identify any changes in the prices of bedding materials and the impact of changes in the bedding material markets on demand for the bedding materials produced, imported and/or sold by the responding companies during the last 12 months. All responded that there had been price changes. Of all respondents, 85% stated that there had been changes in the prices of the bedding material products produced, distributed and/or sold by their companies. Price increases were mainly related to wood shavings and sawdust, while some also mentioned that the prices of pellets had increased.

Half the respondents had seen changes in demand for bedding materials during the last 12 months, whereas one in every ten respondents thought that no changes had taken place. Almost half (40%) were unable to say whether there had been any changes. Demand for peat had increased as a result of increases in the prices of wood shavings and decreases in availability, while demand for wood shavings and pellets had also increased.

Regarding changes in prices and demand, the respondents were asked whether the companies they represented had considered producing and/or selling any bedding materials that they had previously lacked in their product range. Nearly a third of respondents (30%) had considered adding new bedding materials to their range. The new products mentioned varied by respondent, and no general trends could be identified. Of all respondents, 60% had not considered new bedding materials, and 10% could not say.

12.7. Near-future outlook and development needs in the bedding material markets

12.7.1. Near-future outlook for the bedding material markets

When asked about the near-future outlook for the bedding material markets, several responses pointed to the lower availability of wood-based materials in particular and increases in their prices. Currently, wood is used extensively in heat production. As a result, the prices of wood shavings and sawdust will increase, as the price of raw materials used in energy generation has increased and continues to increase. Wood pellets are also increasingly used in energy generation because of the higher price paid. Fewer wood-based bedding materials are therefore available. In addition, the shortage of wood-based bedding materials will keep prices high or even raise them even further. Because many materials suitable for use as bedding materials, including peat, sawdust and wood shavings, are also suitable for use as

energy, their price as bedding materials depends largely on price levels in the energy markets. Energy sources used in heat production will be in short supply in the near future, which is why all materials suitable for heat production will be at the price levels set in the energy markets.

However, a few responses predicted that the prices of wood-based materials could even decrease. The prices of pellets are decreasing as a result of lower energy prices. The availability of pellets was also considered good at present.

One response mentioned that smaller volumes of processed wood products were being produced, due to which the use of wood shavings as raw materials for bedding materials was limited, and prices remained high. The availability of wood shavings and sawdust depend on orders placed at sawmills and planing mills, as well as the availability of sawn logs, because they are by-products of the wood processing industry. Some respondents produce wood-based materials in large volumes.

A few respondents pointed out that if the availability of bedding peat decreased, plant stem-based bedding materials would be in short supply, especially due to higher demand. This was expected to have a significant impact on the prices of raw materials, as a result of which the market price paid by end users would also need to be raised.

Challenges with the availability of peat and the trend of rising prices were pointed to due to the temporary competition resulting from use as energy and in the longer term due to the decrease in the production of peat for energy. In contrast, one respondent stated that there had been no problems with peat, even though they had been predicted.

One response encouraged everyone to acquire bedding materials well before they were needed. When orders are placed early, availability is high, but if everyone delays their orders until winter, production volumes will be insufficient. The availability of certain products during winter is limited by the fact that they cannot be stored in large volumes to await orders, at least as bulk material.

One respondent also pointed out that alternative bedding materials were increasingly under development, and the rising prices of conventional bedding materials increased their profitability and opened new opportunities. It was considered that mixtures of bedding materials would have a higher demand in the future, as the availability of virgin materials, including peat, decreased in the markets.

One response mentioned the chronic cost crisis in agriculture, which called for reasonably priced bedding materials with a guaranteed availability to enable livestock production in the first place. It was also stated that bedding materials were required to ensure animal welfare. Finland's wet and cold conditions underline the significance of bedding materials when it comes to animal welfare.

12.7.2. Development needs related to bedding materials

When asked about development needs related to bedding materials, the respondents pointed out that information about the future of the markets was required. In addition, some required statistics on the use of bedding materials, indicating the amounts used and the types of bedding materials used by region and main production. Information about bedding

materials was also required, including information about the uses of bedding materials, the properties emphasised in the selection of products for various purposes, different ways of purchasing products, delivery methods, etc.

New domestic bedding material options and information about their production capacity were also required. One respondent stated that "*currently, all 'specialised' materials are imported*". Domestic hemp was requested as an alternative for imported materials, and it was mentioned that the production of domestic hemp for use as bedding material should be developed. Hemp was considered a potential addition to crop production in Finland.

Other development needs mentioned included the intensified production of bedding materials on fields. For example, harvesting, including cutting, crushing and transferring to the load space, should be possible using a single machine.

Furthermore, new bedding materials should be tested in different applications, and the development of production and processing methods for new products should be promoted. The costs of using bedding materials that replaced peat and their impact on animal health should be studied. In addition, long-term research was required to provide information that was not based on any specific situation.

One response pointed to significant interest in producing bedding materials, provided that there were markets for them. If there is sufficient demand, the establishment of a production plant would be considered seriously. There was interest in producing materials packaged in various ways. The respondents requested the production of domestic materials. Another important view was that the markets were increasingly shifting to renewable bedding materials that had the smallest possible carbon footprint.

12.8. Summary of the survey targeted at companies

The business survey's response rate was fairly low, which partly made it more difficult to interpret the results. However, the responses helped draw the overview that there were only a few producers of bedding materials. Commercial products are mainly wood-based materials, followed by straw pellets. Markets and production of new types of bedding materials are still quite small, but there is interest in new less produced and used materials.

Domestic bedding materials are produced practically everywhere in Finland. Imported bedding materials are delivered directly to users. In other words, users purchase them directly from importers. As expected, horse stables are the most significant users of purchased bedding materials.

The quality of products and raw materials is high. The further processing of bedding materials mainly consists of pelleting and packaging. Fine dust-generating material is removed from wood-based materials.

Delivery as bulk material is the most common delivery method for bedding materials. Packaged products are transported especially over long distances. This helps reduce transport costs, as goods can also be transported during the return trip. More packaged goods can usually be loaded in the same space as bulk material, in which case a larger amount of material can be transported.

13. Analysis of the costs of bedding materials

The generation of the costs arising from bedding materials and bedding is far from simple. Prices are determined based on the costs arising from the production of materials or the procurement of raw materials. Other costs come from processing, including drying, shredding or pelleting. In the case of packaged materials, packaging creates additional costs. Transport and storage also generate costs. Commercial operators also need to address any costs arising from sales and marketing.

The prices of bedding materials are also determined based on whether the material is already an established product or a product still in the development or piloting phase. The prices of products in the development and piloting phases develop when production intensifies and stabilises.

Any unexpected external changes may be reflected in the bedding material markets and therefore in the prices of bedding materials. An example of this is Russia's invasion of Ukraine, which has significantly affected energy markets, among others. Because of the resulting energy crisis, significant amounts of wood-based materials suitable for use as bedding materials have been delivered for energy generation, which has increased competition and prices. In contrast, the availability of straw depends on the amount of crops and weather conditions. Any increases in extreme weather conditions may have a significant impact on the amount and quality of harvested or cultivated straw and therefore on prices.

A price must be set for bedding materials produced on farms similarly to when purchasing them from an external provider. For example, the harvesting, transport and storage of bedding materials generate costs, as does any further processing.

On farms, bedding costs are affected not only by the price of bedding materials but also especially by the amounts used. The amounts used are based on the production method and environment, the number and density of animals, bedding practices, and the bedding materials available and their properties. When calculating bedding costs, it is necessary to address storage costs, any needs of further processing, including shredding, and any labour and machine costs arising from the bedding process. Bedding costs also consist of the amount, value and further use of the manure generated.

Because the price of bedding materials is the sum of many parts, and not all underlying factors can be directly affected, price fluctuations and the unpredictability of prices should also be prepared for in the future.

14. Further use of manure

Bedding materials and the amounts used have an impact on the amount and composition of the manure generated. As faeces and urine are rich in nutrients, including nitrogen and phosphorus, they are valuable fertilisers. The value of manure as a fertiliser has increased especially as a result of the increase in the prices of artificial fertilisers. Regarding the further uses of manure, it is most commonly spread on fields as a fertiliser and soil improvement agent. Companies that produce soil and soil improvement agents also receive various types of manure. Products are used in landscaping or home gardens.

When manure is used as a fertiliser, it should be noted that when faeces and urine are mixed with the bedding material, the nutrient content of the generated manure and the use of nutrients may differ compared to faeces and urine alone. This is affected by the nutrient content of the bedding material used and the amount of bedding materials used relative to the amount of faeces and urine generated. In addition, the processing of manure before its use as a fertiliser, including separation and composting, has an impact on the nutrient content of manure and the use of nutrients.

Most nutrients contained by manure are bound in the organic matter of manure, i.e. non-digestible feed separated from manure and bedding materials. Micro-organisms release the nutrients contained by manure after the disintegration of organic matter, which may take place during manure storage or only after spreading. The release of nutrients from manure is affected by the bedding material used and its composting. For example, peat and plant stem materials decompose fairly quickly, whereas wood-based materials, including wood shavings and sawdust, decompose poorly. Poorly decomposing materials bind nitrogen for their disintegration, which reduces the nutrient value of manure used as a fertiliser.

Any weed problems must be addressed in bedding material cultivation. If weeds are mixed with the harvested material, their seeds may end up in the bedding material and return to the field through manure. However, further research into the realisation of such a weed risk is required.

Seeds may also fall from feed waste into manure and gain access to the field. However, at least some seeds lose their ability to germinate when the bedding or manure storage is composted and heats up (Johansen et al. 2012).

Because the use of manure as a nutrient source for crops and as a soil improvement agent is a significant part of the nutrient cycle on farms, further uses of manure should be addressed. It is therefore not enough that a bedding material has good bedding properties, as it must also have good further uses that promote the circular economy.

The further use of manure and its properties as a soil improvement agent and a raw material for soil are significant factors in horse husbandry in particular, as only a third of all horses are on farms that can use manure on their fields. If manure is not spread on fields on farms, it can be delivered to farmers or horticultural enterprises, or for further processing based on agreements. Peat-containing manure is the most desirable type of horse manure delivered for use as a fertiliser. Manure based on straw and straw pellets are also in high demand. In contrast, wood-based manure is less well accepted until it has been composted or after a longer storage period.

Manure also has a high biogas production potential. However, Finland's sparse biogas network restricts the use of this potential.

Manure can also be burned at waste incineration plants to generate thermal energy (Manninen et al. 2016), but this is not currently done. Fortum Corporation was engaged in large-scale manure incineration at its Järvenpää energy plant between 2015 and 2020, but the operations were discontinued after the ownership of the plant changed. Other incineration trials were also conducted at other energy plants at about the same time. The legal amendments of 2018 also enabled the incineration of animal manure in small and medium-sized units of at most 50 MW, which is regarded as energy generation instead of waste incineration. However, measuring flue gases is so expensive that incineration is not financially feasible. In addition, pyrolysis (heating at high temperatures of 400–500 °C without oxygen affecting the process, i.e. dry distillation) is a potential application for manure (Tiilikkala et al. 2013) not only in energy but also biochar generation.

15. Bedding material studies and their key results

Recent research projects related to bedding materials and their key results are listed briefly below. More information about the projects and their results is available in the published research reports and other texts.

Promoting animal welfare using new material solutions and practices: Towards a future free of animal diseases through multidisciplinary research (NoZoon), project period from 1 April 2021 until 31 December 2023

The goal of the NoZoon project is to identify competitive alternatives for bedding peat to maintain the high quality of Finnish broiler production, the good situation of the low prevalence of animal diseases, and animal welfare. It also aims to study and develop antiseptic bedding materials in particular.

A bedding material trial was conducted at Luke's research site in Jokioinen, comparing eight different bedding materials or their mixtures with broilers. The tested materials were sphagnum moss, willow chips, hemp, a mixture of sphagnum moss and shredded reed canary grass, a mixture of sphagnum moss and zero-fibres, a mixture of willow chips and wood shavings, a mixture of hemp and wood shavings, and zero-fibres with the addition of a willow extract. The control group consisted of peat and wood shavings. The trial aimed to study growth, feed intake, feed utilisation, mortality, gastrointestinal microbiome, cleanliness and foot health in broilers when using different bedding materials.

The bedding materials used had no impact on broiler performance. In other words, no differences in bird growth or feed efficiency were found when using different materials. In contrast, certain differences were identified in foot health and the cleanliness of bird feathers. Birds that had grown using bedding peat, wood shavings or sphagnum moss had the healthiest feet, whereas foot health was poorest in birds that had grown using willow chips or hemp. In addition, the foot health of birds that had grown using a mixture of willow chips and wood shavings or zero-fibres with the addition of a willow extract was poorer than normal. A mixture of sphagnum moss and zero-fibres, a mixture of hemp and wood shavings, and a mixture of sphagnum moss and reed canary grass were fairly effective in terms of foot health. Feathers were the cleanest in birds that had grown using bedding peat or a mixture of sphagnum moss and zero-fibres, almost half of which were grouped in the cleanest category on a three-step scale. Birds that had grown using willow chips and zero-fibres containing a willow extract had the dirtiest feathers, roughly a third of which were grouped in the dirtiest category.

The research results have yet to be published.

Hygienisoitu lanta, project period from 1 May 2021 until 31 August 2023

The need for the project originated in horse manure, which had been found problematic in Southern Finland. The problem mainly arose from the difficulties of horse companies in finding clients for manure, especially in cities and urban areas and in hubs with a large number of horses. The project's goal is to develop manure into a marketable soil improvement agent in accordance with the EU animal by-products regulation. In addition, the project studies the use of hygienic horse manure as a bedding material. The project's goal is therefore to promote the development of hygienic dry solids separated from manure and other hygienic

manure varieties into higher value-added products and as a result, increase the profitability of horse and livestock farms and contribute to the circular economy. Hygienisation carried out on farms eliminates a significant bottleneck in the further processing of manure.

The project tested the operation of the ManPas manure hygienisation machine developed by IP-Innovaatiot Oy to make manure hygienic. It is an instant hygienisation method, in which the manure temperature is raised to +70 °C, and the manure is processed for one hour. The bedding material trials conducted using hygienic horse manure showed that it had significant potential as a recycled bedding material, especially if the stable, hygienisation unit and the site for further use were within logistically reasonable distances of each other. Further research is still required for different solutions, in which a stable or horse hub makes manure hygienic and recycles it by using it for private purposes.

The research results have been published in:

- Rantala, M. 2023. Horse manure as recycled bedding for dairy cows. Master's thesis, Häme University of Applied Sciences, Development of bioeconomy business. 35 p.

Towards decentralised biogas production from dairy farms at Northern Savonia II (FarmGas-PS 2), project period from 1 June 2021 until 31 August 2023

The project aims to create a techno-economically feasible and sustainable operating concept in Northern Savonia, where biogas production is decentralised, taking place on farms or in small joint biogas plants with an annual capacity of less than 20,000 tonnes of feedstock per year. However, the energy is utilised centrally, either as compressed biogas or as liquefied biogas. The scenarios developed in the project serve as basis for future actions. One part of the project involves the development of the utilisation of solid fractions of digestate and raw slurry, and willow as bedding material for dairy cows.

Mixing compressed fibres generated as a side stream of the wastewater purification process, reed canary grass and willow chips with dry solids separated from biogas plant digestate and dry solids separated from slurry were studied at laboratory scale. The purpose was to provide information about the physical properties and safety of the tested bedding material mixtures.

The use of willow was studied as a base material of the deep bedding area whereas straw was studied as a bedding material. The results provided more information about the properties of willow as a bedding material and experiences of its use. For willow, this was a new application, and the aim was partly to find new uses for peat fields that were no longer in use.

The amounts of dry solids separated from slurry were measured at Luke Maaninka dairy barn. In addition, mass and nutrient balances were calculated in the separation of digested residues and slurry, and they were compared with the separation results of previous projects. The use of reed canary grass as a bedding material as such in stalls and mixed with separated manure in deep bedded stalls was studied to a smaller extent.

Separated manure was also tested on commercial milk production farms. It was tested as such and mixed with reed canary grass. In addition, mass and nutrient balances related to bedding separation were calculated for the trial farms.

The project also prepared disinfection instructions for a jointly used separator and instructions for determining the solid content of dry solids using a halogen dryer.

The research results have not yet been published.

Kuiviketurpeen korvaajat broilerituotannossa, project period from 1 August 2021 until 31 July 2023

The project conducted by Seinäjoki University of Applied Sciences and Biolan Oy studied options for replacing peat and their mixtures in poultry production. The project studied the drying and further use properties of various bedding materials, as well as the hygienic quality, safety, usability, availability, price and environmental impact of each material. In addition, it examined the financial profitability of bedding materials and the impact of manure on the nutrient cycle and fields. The project identified the properties of bedding materials at a laboratory scale and conducted bedding material trials on farms.

Further information about the project: https://projektit.seamk.fi/kestavat-ruokaratkaisut/kuiviketurpeen-korvaajat-broilerituotannossa/

Orgaanista voimaa peltoon ja parteen (OrVo), project period from 1 January 2020 until 30 November 2022

Additives affecting the acidity of bedding materials have been found to curb microbial growth (Hogan et al. 1999). As the pH of separated manure is neutral or slightly alkaline additives that increase alkalinity are the most effective (Hogan et al. 1999), including lime (Robles et al. 2020).

The addition of ash eligible for spreading on fields (15 mass per cent; Mäntän Energia Oy) to separated manure was tested at Luke's research barn in Maaninka (Frondelius et al. 2023). During the first four-week trial period, one animal group was bedded with separated manure treated with ash, while the other group was bedded with untreated separated manure, after which the bedding material treatments were changed between the groups for another four-week trial period. Cow cleanliness was assessed, and milk samples were taken to determine somatic cell count in milk once a week. Bacteriological milk samples were taken based on the California mastitis test (CMT). The microbiological quality of bedding materials was determined using microbiological culture tests and the qPCR analysis.

The addition of ash to separated manure increased the pH value and dry matter content. The average dry matter content was 26.0% in untreated dry solids and 34.9% in ash-treated dry solids. The addition of ash to separated manure had no impact on cow cleanliness or the number of somatic cells in milk, which on average was on excellent level in both bedding materials.

Based on the microbiological analyses of the bedding materials, the bedding material treated with ash contained fewer microbes. However, the sampling time had a much more significant impact on the number of microbes than the bedding material. In both bedding materials, the number of microbes increased over time, being lowest immediately after spreading the bedding and highest after two days. In addition, the statistical difference in the number of microbes between ash-treated and untreated separated manure in unused bedding materials disappeared after one day in use.

The addition of ash eligible for spreading on fields to separated manure only produced marginal benefits considering the microbiological quality of bedding materials. Similar results

have also been achieved in other additive studies (Hogan et al. 1999, Bey et al. 2009). One of the most effective ways to control the microbial load of bedding materials in stalls is to have a sufficiently short bedding interval (Janzen et al. 1982, Robles et al. 2020), which is also supported by the results of this trial.

The final results will be published during the autumn of 2023:

- Frondelius, L., Lindeberg, H., Ruuska, S. & Pyykkönen, V. 2023. Microbes under control by adding ash to dry solids? In: XX (ed.). New methods to intensify the nutrient and organic matter cycle on cattle farms – OrVo project results, Natural resources and bioeconomy studies XX/2023, pp. XX–XX.

Renewable bedding materials to replace use of peat (Turveke), project period from 1 August 2019 until 31 December 2021

The properties of potential bedding materials to replace peat were studied on a laboratory scale in two phases at Luke's research site in Jokioinen. Some of the materials were agricultural or industrial by-products, and some were produced as bedding materials. The first phase included 16 materials: plant stem materials, by-products of the wood processing and mill industries, textile waste, biochar and ground willow. Based on the fluid retention capacity, ten of these were selected for the second phase. In both phases, bedding peat formed the control group. There were differences in the properties of various materials, which is why they could not be ranked in any specific order. The materials had some good properties regarding certain measured parameters and weaker properties regarding other parameters. Some of the materials may be effective in mixtures, but no mixtures were compared in this study.

The bedding materials were compared using broilers at Luke's research site in Jokioinen. The compared materials were shredded common reed and reed canary grass, as well as sphagnum moss, each of which were compared with bedding peat. No differences were identified in the production results of birds when using different bedding materials during the entire period, but the cleanliness and foot health of birds was significantly better when peat and sphagnum moss were used than when plant stem materials were. Based on the results, sphagnum moss is on a par with peat as a bedding material. Due to bird dirtiness and poorer foot health, shredded reed canary grass and common reed are unsuitable for use as bedding materials with broilers, at least when used exclusively.

The use of bedding materials with horses was tested at Luke's former research site at Ypäjä Equine College. In the test, wood-based crumb pellets, reed canary grass pellets and textile bricks were compared with bedding peat. Wood-based crumb pellets, reed canary grass pellets and peat formed a good bedding in pens. In the middle of the test period, pens bedded with reed canary grass pellets were noticeably wet, meaning that their fluid retention capacity decreased when using the amounts indicated by the manufacturer, which is why bedding was intensified. Textile bricks were less effective as bedding materials than the other materials. Manure and wet patches were difficult to identify in the bedding material, which increased the amount of waste. In addition, the bricks were heavy, generated a lot of dust, and showed signs of discolouration when wet. Except for textile bricks, the other tested materials were suitable for use as replacements for peat with horses.

Shredded reed canary grass was compared with peat as bedding material of finishing bulls in uninsulated barn at experimental cattle unit of Luke in Siikajoki. Measured in kilograms, much

more peat was consumed than shredded reed canary grass. Both materials kept animals clean. Reed canary grass generated more heat than peat. Although peat had higher moisture content, the difference could not be seen in the dry matter content of the bedding. The amount of dust generated was a significant disadvantage of reed canary grass. Shredded reed canary grass proved itself a noteworthy bedding material for replacing peat as a bedding material for cattle.

In addition, the project examined the climate impact of the aforementioned bedding materials compared in practical conditions. The results showed that the almost all the studied materials had a smaller carbon footprint than peat. Shredded common reed had a negative carbon footprint, meaning that its use helps mitigate climate change. In addition, textile bricks and reed canary grass grown in mineral soil had a smaller carbon footprint than peat. The carbon footprint of sphagnum moss was at the same level as peat, considering the amount required compared with peat. Wood-based crumb pellets had a larger carbon footprint than peat. In contrast, the carbon footprint of reed canary grass varied greatly depending on the soil type, harvest level and the amount of roots.

The research results have been published in:

- Manni, K. (ed.). 2022. Alternative bedding materials replacing peat. Natural resources and bioeconomy studies 9/2022. Natural Resources Institute Finland. Helsinki. 108 p.
- Lehtoranta, S., Johansson, A., Myllyviita, T., Grönroos, J. & Manni, K. 2021. The climate impact of alternative litter materials for peat. Reports of the Finnish Environment Institute 51/2021. 80 p.

New bedding solutions for cattle farms (Nauku), project period from 1 July 2018 until 30 June 2021

Different bedding materials were compared with peat as bedding material of finishing bulls in uninsulated barn at experimental cattle unit of Luke in Siikajoki. There were four test periods. The tested bedding materials were peat, straw, reed canary grass, hay, cardboard cores and non-composted peat-based horse manure. Some of the materials were used exclusively as bedding materials, while some were used in mixtures. The bedding materials differed during each test period.

Although there were fairly significant differences in the dry matter content of the bedding materials, they were not reflected in the dry matter content of bedding. Reed canary grass and straw proved to generate heat well. Horse manure had the lowest ability to generate heat. It was tested with straw or peat.

In addition, the preferences of young bulls between straw, reed canary grass and horse manure were studied in uninsulated barn at experimental cattle unit of Luke in Siikajoki. Indicators included the time spent on each bedding and the probability of lying down.

Reed canary grass and straw were enjoyable bedding materials, whereas horse manure was significantly less comfortable. One of the reasons for the low popularity of horse manure may have been its high moisture content. The differences in the dry matter content of the different materials evened out as testing progressed, and the popularity of horse manure also increased. Getting used to horse manure as a bedding material may have required some time from the animals.

The research results have been published in:

- Manni, K. & Huuskonen, A. (ed.). 2021. New bedding solutions for cattle farms. Natural resources and bioeconomy studies 54/2021. Natural Resources Institute Finland. Helsinki. 113 p.

Lantalogistiikan kehittäminen karjatiloilla (ManureLogistics), project period from 30 June 2015 until 30 June 2019

Separated manure was compared to peat on dairy cows in a freestall barn with mattress stalls at experimental cattle unit of Luke in Maaninka. During the first 13-week trial period, one animal group was bedded with separated manure, while the other group was bedded with peat, after which the bedding material treatments were changed between the groups of another 13-week trial period. During the trial, skin lesions in hocks and carpal joints and cleanliness in rear feet, the rear quarter of the body and udders were assessed, and the number of somatic cells in milk was determined. In addition, a bacteriological milk sample was taken from cows whose cell count was more than 400,000 cells per ml.

The trial showed that there was less skin alterations in hocks when separated manure was used compared to peat. In addition, udders were cleaner when separated manure was used. In most milk samples (>75%) taken regardless of bedding material, the number of somatic cells in milk was less than 150,000 cells per ml. There were no statistical differences in the number of somatic cells between the bedding materials. Coagulase-negative staphylococci (CNS) were the most common pathogen finding in both bedding materials. Environmental mastitis pathogens were only found when using separated manure. However, these were individual cases and did not differ from normal prevalence in the herd. Based on the results, the use of separated manure did not significantly reduce udder health, while the link between the bedding material and mastitis infections could not be fully excluded.

The research results have been published in:

- Frondelius, L., Lindeberg, H., Pastell, M. 2020. Recycled manure solids as a bedding material: Udder health, cleanliness and integument alterations of dairy cows in mattress stalls. Agricultural and Food Science 29: 420–431.

Testing straw pellets in MTT stables, project period from 17 until 30 November 2009

Bedding of horse boxes using domestic pellets made from barley and wheat straw was tested in the horse research stables of the Agricultural Research Centre of Finland (MTT). The colour of the pellet was dark green, and the odour resembled pelleted hay. The light colour of broken pellets resembled that of straw. This was the first test of its kind, and there was practically no prior experience of using straw pellets as a bedding material for horses.

The pellets were very hard, and horses required time to get used to them. Straw pellets, which are mainly of foreign origin, have since been made softer so that they break more easily under horses' hooves than harder pellets. This is an important property. Handling pellets by hand during the first bedding stage was hard work, as they were so heavy (680 kg per m^3). Based on the test, straw pellets were very suitable for use as bedding materials in horse pens, as they kept the air quality high based on a sensory assessment, and no dust was generated. Boxes were easy to clean using a light dung fork, and little bedding material was wasted.

16. Short- and long-term research and development needs for bedding materials

16.1. Roadmap for bedding material supply

To secure the supply of bedding materials in the constantly changing environment, we need alternative effective solutions for various needs and situations. In addition, we require effective cooperation models and incentives to develop bedding material supply into an activity that is effective, sustainable and profitable for all parties. Although the availability of bedding materials remains fairly high, now is the time to prepare for the changes expected especially in the availability of bedding peat.

Preparing for and adapting to changes call for proactivity, plans and concrete actions from bedding material producers and users alike. It will be important to also ensure the future availability of existing well-functioning bedding material solutions. It will be at least as important to carry out development to find new alternatives and solutions. Innovation calls for courage and risk-taking to create and try something new. It should be kept in mind that options that are currently under development and testing may offer solutions for the supply of bedding materials in the future.

Finding common guidelines and aiming to secure the supply of bedding materials now and in the future will be key, for which a comprehensive vision and effective interaction will be required. The various operators in the sector need to engage in even closer cooperation. Preparing a roadmap for bedding material supply between industry operators has been proposed as a solution.

During the first phase, tangible measures to secure the supply of bedding materials should be defined to solve the expected acute shortage of bedding materials. In addition, it is also needed long-term development to secure the sustainable supply of bedding materials. The roadmap can be based on this report on bedding materials, among others.

16.2. Research needs

Further research is required regarding animal farming and welfare, various uses and working methods, the costs of bedding material production and handling, and the planning of the machine chains and processes required. It is important to identify the factors that determine how the supply of bedding materials matches their demand.

The list below presents key research themes related to bedding material supply for which further research is required. It also includes needs raised in the producer and business surveys.

- Ensuring the availability of bedding materials
- Properties of bedding materials exclusively as bedding materials and in mixtures
- Suitability of bedding materials for various uses
- Healthiness of bedding materials for animals and people, also considering food hygiene

- Technical solutions required for bedding: harvesting; processing needs; storage; transport; use
- Processing needs and benefits of bedding materials
- New materials and their potential and production capacity
- Costs
- Overall sustainability (LCA)
- Further use of manure
- Promoting cooperation between farms
- Statistical information on the use of different bedding materials by production sectors and by regions, as well as information on production volumes of bedding materials
- Market survey: What bedding material properties are to be emphasised in different intended use and product selections? How should products be purchased and delivered?

16.3. Developing bedding material markets at different levels

Various bedding material operators are required to secure the supply of bedding materials. Decentralising the bedding material markets at different levels may reduce risks associated with the availability of bedding materials. In addition to nationwide supply, production may be very local or regional, using regional strengths and opportunities in particular.

More and different types of bedding material producers and users are also needed. Imported materials, including hemp and straw pellets, could offer potential to produce domestic bedding materials. In addition, the use of industrial side streams may open new opportunities for bedding material production. Forest industry sludge is a good example of this.

Bedding material cultivation on a larger scale than at present could offer one future solution in the development of bedding material supply. It could offer new opportunities especially on farms that have unused fields or parcels that are unsuitable for the production of crops for human consumption. For example, reed canary grass and hemp could be potential crops for this purpose.

Furthermore, cooperation between farms is still an ineffectively used solution to secure the supply of bedding materials. Livestock and crop production farms in particular could significantly increase cooperation in bedding material production, with crop production farms cultivating or producing bedding materials for livestock farms. Reed canary grass would diversify crop rotation and increase plant cover round the year on crop production farms. Alternatively, cattle farms could obtain straw from crop production farms for use as a bedding material, and correspondingly, cereal crop farms could receive straw back as manure. In the development of such activities, organising the spreading of manure and acquiring the machine chain required for the collection and handling of bedding materials are key factors.

Bedding material users should be encouraged to test new bedding materials or mixtures if possible. This would be part of risk management if certain materials are unexpectedly in short supply. Networks of producers in the procurement and production of bedding materials may also present solutions for securing the supply of bedding materials.

17. Summary

If the estimates of the amounts of bedding materials made based on the information obtained are realised, there will be a shortage of bedding materials in the near future. This will especially be affected by the halving of the amount of bedding peat from its current level during the next five years. In addition to peat, the amount of wood-based bedding materials will also decrease, as competition has become fiercer. A key reason for this is the energy crisis, as a result of which demand and competition regarding materials suitable for energy generation has increased. During the last year, sawdust and wood shavings produced at sawmills have been increasingly forwarded to energy generation. According to current estimates, wood-based bedding materials (wood shavings and sawdust) will be in short supply in the near future. The availability of straw pellets has also decreased.

Increased competition has also been reflected in higher prices. This became evident in the surveys targeted at producers and bedding material companies. In addition to ensuring the availability of bedding materials, it is important to address their cost impact. As bedding is a key part of animal welfare and health, and partly of food hygiene, sufficient and effective bedding cannot be compromised. It is therefore absolutely essential to address the costs arising from bedding as well in ensuring the supply of bedding materials.

To secure bedding material supply in every situation, we need to primarily ensure the availability of current and effective bedding materials, at least until they have effective options with competitive prices and sufficient availability. Ensuring the availability of bedding peat in particular and its further development should not be undermined. The sufficient availability of bedding peat must be ensured at least until any supplementary and/or replacement materials are at the level of production to match the current use of peat. This will take years and cannot result in a situation where animal welfare suffers from insufficient bedding due to the lower availability and higher prices of bedding materials.

The predicted decrease in the number of animals will reduce the need for bedding materials to some extent. Decreases can be seen especially in the cattle sector, but also in the number of pigs and chickens. More moderate changes are expected in broiler production, and they are not expected to have an impact on the bedding material markets. The number of horses is expected to remain unchanged in the near future.

In addition to the expected changes in the number of animals, the need for bedding materials depends on various other factors that may increase demand for them. Examples include potential changes in production methods, such as increases in uninsulated buildings, the floor rearing of chickens and bedding material-based bedding areas, as well as investments in measures to improve animal welfare.

Peat is the most critical bedding material in broiler production. It is difficult to find a bedding material to replace the use of peat in broiler production to secure the high foot health and antibiotic-free production of birds. Sphagnum moss offers a potential bedding material for broilers, but its use is limited by its availability. Further research is also required to identify the environmental impact of sphagnum moss extraction. Materials that replace and supplement peat are already available for cattle, horses, sheep and pigs. However, their sufficiency is a critical factor, as certain materials are already in short supply.

Straw is a widely known and used bedding material, while not all its potential has yet been used. As nearly all straw pellets used in bedding are currently imported, there could be potential markets for their domestic production. However, when harvesting straw, it should be ensured that the amount of organic matter in soil is not reduced, and the soil structure is not harmed. This can be compensated for by returning straw to soil through manure, also including the valuable nutrients contained by manure.

The potential of slurry and manure as bedding materials has yet to be fully utilised. The separated manure can be used as a bedding material for cattle. The cost of processing manure produced on farms into bedding materials is not high after the initial investment, and it enables farms to be self-sufficient in bedding materials. The possible use of manure as a bedding material for other animals as well requires research.

The use of side streams from the wood and sawmill industries as bedding materials should be promoted. Forest industry sludge is a good example of this. Furthermore, the potential of natural materials, including sand, common reed, reed canary grass and peatland biomasses, as bedding materials should be studied and advanced further.

Bedding material cultivation is also one way to increase the production of bedding materials. Suitable crops for cultivation include reed canary grass and willow. Another advantage of reed canary grass is that it can act as a feed buffer for cattle if forage is in short supply. Shives, by-products of the further processing of hemp fibres, can also be used as a bedding material. If domestic hemp fibre processing is scaled up, it is possible for domestic hemp-based bedding materials to be available. Currently, the use of hemp in bedding materials relies on imports. An increase in paludiculture would enable the cultivation of bulrush as a bedding material. Reed canary grass is also suitable for paludiculture. However, promoting bedding material cultivation calls for incentives and effective markets.

Cooperation between farms is still an ineffectively used solution to secure the supply of bedding materials. Livestock and crop production farms in particular could significantly increase cooperation in bedding material production. In addition, cooperation between farmers should be promoted in both the procurement and production of bedding materials. However, this calls for incentives, effective markets and good practical examples.

It is evident that promoting the use of new materials to be developed calls for the cost-effective development of harvesting, further processing, storage and transport. It must also be ensured that the supply of bedding materials is secured in an environmentally sustainable manner.

The availability of many materials would have to be improved significantly if their use increased considerably. Even if the availability of a certain potential bedding material was high, its properties might require processing. This usually increases costs and may therefore limit the use of the material. Market surveys are also needed to produce the bedding materials required and find the correct target groups for different materials.

It should be understood that options that are currently under development and testing may offer solutions for the supply of bedding materials in the future. More research and innovation, as well as courage from businesses to invest in bedding material production, are needed to produce new solutions. It should be understood that bedding material markets that operate at more and different levels than at present may be needed in the future. Some bedding

material production may be very local, including cooperation between farms, while some may be regional, and some may be national.

Finding common guidelines and aiming to secure the supply of bedding materials now and in the future will be key, for which a comprehensive vision and effective interaction will be required. The various operators in the sector need to engage in even closer cooperation. The preparation of a roadmap for bedding material supply could be one way to promote this. During the first phase, concrete measures to secure the supply of bedding materials should be quickly defined to solve the expected acute shortage of bedding materials. In addition, we require long-term development to secure the sustainable supply of bedding materials.

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