Investigation of the factors affecting the insulation properties of down-filled clothing

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ABSTRACT – REZUMAT

Investigation of the factors affecting the insulation properties of down-filled clothing

Goose down is an ideal raw material used in producing many products because it is light and bulky, has low thermal conductivity, and has the best thermal insulation properties. Due to its light, soft and warm-feeling structure, these feathers are considered a superior and luxurious filling material for bedding and clothing against the cold climate.

Nowadays, goose down is used in the production of some items such as souvenirs or ornaments, in the production of pillows and quilts, in the production of winter alpinist and ski clothes, sleeping bags, and seat production.

Goose down is an excellent insulation material and its performance can be improved by the appropriate design and production method. Clothes or sleeping bags made from goose down are usually made of baffles. Feathers are filled by hand or machine to these baffles which can be produced in different constructions. Several factors influence the thermal insulation of a goose-down-filled product. The most important factors are fill power, goose down weight and goose down rate. In this study, the production of goose down products and the factors affecting the thermal insulation properties of these products were investigated.

Keywords: *goose down, clothing, filling fibres, thermal resistance, thermal insulation*

Investigarea factorilor care influențează proprietățile de izolare ale îmbrăcămintei umplute cu puf

Puful de gâscă este o materie primă ideală folosită în fabricarea multor produse, deoarece are o masă redusă și este voluminos, are conductivitate termică scăzută și, prin urmare, are cele mai bune proprietăți de izolare termică. Datorită structurii lor ușoare, moi și care oferă căldură, aceste pene sunt considerate un material de umplutură superior și de lux pentru așternuturi și îmbrăcămintea de protecție la frig.

În prezent, puful de gâscă este utilizat în producția unor articole precum suveniruri sau ornamente, în producția de perne și cuverturi, în producția de îmbrăcăminte pentru iarnă pentru alpinism și schi, saci de dormit și în producția de scaune. Puful de gâscă este un material de izolare excelent și performanța acestuia poate fi îmbunătățită prin proiectare și metoda de producție adecvată. Articolele de îmbrăcăminte sau sacii de dormit cu puf de gâscă sunt, de obicei, fabricați din buzunare despărțitoare cu aer (”baffles”). Penele sunt umplute manual sau mecanic în acestea, putând fi produse în diferite tipuri de construcții. Există mai mulți factori care influențează izolarea termică a unui produs umplut cu puf de gâscă. Cei mai importanți factori sunt puterea de umplere, greutatea pufului de gâscă și cantitatea pufului de gâscă. În acest studiu au fost investigate fabricarea de produse din puf de gâscă și factorii care influențează proprietățile de izolare termică ale acestor produse.

Cuvinte-cheie: *puf de gâscă, îmbrăcăminte, fibre de umplutură, rezistență termică, izolare termică*

INTRODUCTION

Human beings have benefited from waterfowl in various ways for thousands of years. During domestication, humans consumed the meat of wild birds, used their fat for lighting and heating, and their feathers for warmth [1].

Feather is a tissue in all poultry animals and covers the body. Feathers are a necessary structure for many purposes in poultry, such as flight, heat insulation, giving shape and colour to the body,

and preventing injuries [2, 3]. Like human hair and nails, feathers of poultry are made of keratin [4]. Feather is also a type of raw material used especially in the textile industry.

Among poultry, waterfowl feathers are the most valuable. The underparts and body feathers of water birds have a wide range of uses for humans. These feathers have important features.

The main features of these are natural insulation, ability to hug the body, breathability and low allergenic level (hypoallergenic) [5]. For this reason, waterfowl feathers are used as a natural filling and insulation material in the production of high-quality products [6]. Assuring the thermal stability of the human body is one of the most important functions of clothing. Its thermal insulation properties play a crucial role in a human's heat maintenance, especially in winter conditions [7–10]. Filling materials are generally used for trapping air and providing insulation. The insulation and comfort levels mainly depend on the type and amount of filling material as well as on the filling method [11]. Goose down is the most common natural filling raw material.

Goose down has been used to fill pillows and duvets for more than 2000 years. Today, goose down is used in furniture as well as in quilts, winter clothes, sleeping bags [12], bedding, and winter mountaineering and ski clothes [13–15]. Goose feathers are also used in the production of various ornaments and quality badminton balls [6]. Goose down is an ideal raw material for the production of many products with its lightness and unique insulation properties [16].

Properties of goose down

Goose down, each feather set consists of multiple branches extending outward from a central point. Each of these branches has fine fibres with knots on it [17]. Their structure is three-dimensional and since their clusters are composed of interlocking fine barbs, they attach and thus create millions of tiny air spaces trapping air. Due to the characteristics of lightweight, soft touch and warm feeling, the downs have long been considered superior and luxurious as a filling material for bedding and outerwear against cold climates [18].

The factors affecting the insulation properties

In the outdoor industry, down quality is usually assessed and sold using two main measurements: The down to feather ratio, and the fill power and garment structure [19].

Down-to-feather ratio: The down-to-feather ratio calculates the percentage of down to the percentage of feathers in the product. The blends are generally 70/30, 80/20, or 90/10 of which the first blend amount represents the percentage of down, and the second one represents the percentage of feathers.

Fill power: Fill power is the universal rating system for goose down [20]. Down fill power is a measure of the loft or 'fluffiness' of the down and its insulating properties. The higher the fill power, the more air pockets in the down and the more insulating the jacket will be for its weight. Fill power is calculated in laboratory conditions and is measured in cubic inches per ounce. To test fill power, an ounce of down is compressed by weight in a glass cylinder. Its ability to bounce back and 'loft' is calculated as the fill power. Fill power is also an indication of the quality of the down used. The better the quality of down the higher the fill power. As less down is required to provide the same amount of warmth, jackets with a higher fill power tend to be lighter and more compressible [21]. Down jacket fill power ratings are given in the following:

Fill Power	Rating
400 – 450	Medium
500 – 550	Good
550 – 750	Very Good
750 – 900	Excellent

For down outerwear ratings will generally fall between 600 and 800.

Filling quantity: Filling is carried out by machine. Filled materials come to the sewing department for joining.

Fig. 1. Goose down filling machine

In garments with box-shaped components, the different width of the compartments allows the goose feathers in different proportions. Different filling rates are available in different parts according to the environmental conditions in which the garment will be used. A larger amount of fluff is usually applied to the compartments in the chest and back section of the garment. This rate is lower in the arms and shoulders. This is because the use of more feathers on the shoulders disrupts the overall appearance of the garment.

Garment structure: The construction of the garment is another factor affecting the insulation properties.

Baffles: Down jackets are usually constructed by using a series of compartments called "baffles". Baffles are the pockets of space that are created between two layers of fabric which then hold the goose or duck down that is in the jacket. The size and construction of the baffles have an impact on the effectiveness of the insulation. The compartments eliminate the possibility of goose down movement, ensure that the insulation is equal and minimize the areas that can get cold. The dimensions of these compartments may be different from each other. It is the form of these compartments that give its appearance to many of the clothes. These compartments are formed by quilting. These may be box-shaped or have different patterns.

There are two main types of construction using baffles; box wall and stitch-through.

Box wall: The jacket or sleeping bag's filling is formed into channels with box wall construction each baffle

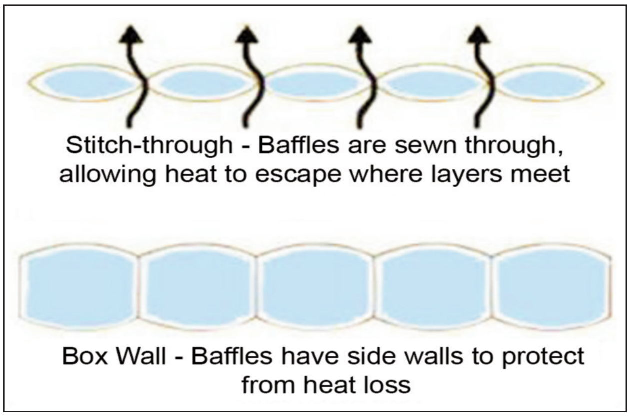

Fig. 2. Types of the baffles

has side walls. These horizontal compartments are designed to hold the down in place around the body and maximize the performance of the jacket [22]. There are nearly every size or pattern (midi, micro, square or zig-zag) baffles. Wider baffles offer better warmth, as they contain more grams of down and can be constructed with fewer seams, so less heat is lost. However, wider baffles make the jacket more bulky and less compressible. Conversely, narrow or micro baffle jackets work best for warmth in spring or autumn, or as technical mid-layers, but compress excellently to be packed away when not needed.

Stitch-through: This method is the most common. It is easier, less time-consuming, and therefore cheaper for manufacturers than other forms of baffle construction. The outer material is stitched directly into the inner lining, separating the down in different baffles, which are horizontally oriented.

This method uses less fabric is lighter than more complicated box baffle construction, and is less costly. Because of weight, simplicity, and cost, most lightweight jackets, and many of the heavier ones utilize this construction. Although stitch-through construction saves weight via the use of less material, it is less warm than box baffle construction because the down is pinched at the seams of the stitch-through baffles and thus loft is reduced to zero at each point of baffle stitching. The stitch-through baffling prevents the migration of the down, but due to the simple construction, it also reduces the optimum loft of the down, creating “cold spots” at each baffle seam. The benefits of using stitch-through baffles are that this method uses less fabric overall and is lighter than more complicated box baffle construction, it helps keep the price of the down jacket low too. Depending on the innovations in sewing technology, welded or bonded baffles are also being produced in addition to stitch-through.

Welded or bonded baffles: This construction technique fuses the inner and outer pieces of fabric to create a baffle that holds them down using heat, chemicals, glue, or a combination of all three. There is one major benefit to these techniques: since there are no holes in the outer fabric from sewing the baffles they are more wind impermeable and water resistant or proof.

Model properties: It’s also important to look at possible routes for cold air to enter the jacket, starting with zips. Because of their structure, zips are air-permeable and cold will find its way in wherever possible, so zips should preferably have a protective, insulated, baffle mounted on either the outside or inside of the zip, hood, hem and cuffs are also important because of each provides a possible route for cold air to enter. Zips are one of the areas where heat loss can occur, particularly the main front zip, so it’s essential to look at features which can reduce or prevent this. Baffles can be placed either inside or outside the zip to prevent heat loss through the zip. An internal baffle will generally sit naturally behind the zip, whereas a baffle on the outside will need holding in place using velcro or snaps.

There is little point in wearing an insulated jacket if cold air gives easy access to the extremities, so hem and drawcord adjustment is essential. While elasticated cuffs can give a good fit the velcro fastening is generally preferable, giving both a better fit and allowing the wearer to adjust the gap to regulate airflow [23].

The collar is one of the most important areas of an insulated jacket. With warm air naturally rising the area around the neck provides the easiest escape so needs special attention. A lined collar with a soft face and a baffle that encircles the wearer’s neck should be used.

In this study, it was aimed to find out the factors affecting the thermal insulation properties of goose down clothing. Since goose down is often used in jacket production, the properties of jackets have been investigated.

MATERIAL AND METHOD

Materials are supplied from Hungary. The down-to-feather ratio of samples used in this study is 80/20 and 90/10. For filling goose down, nonwoven bags of 30 cm × 30 cm were prepared. The weight of the nonwoven fabric is 65 g/m^2 and it is produced from 100% cotton. These bags were sewn with 100% polyester sewing thread. The stitch length was kept constant at 3.5 stitches/cm for all sewing applications. Fiber samples were placed into nonwoven bags. Filling materials weighing 10, 15, and 20 g were placed into each bag respectively.

Before testing, all samples were conditioned for 24 hours under the standard atmospheric conditions (20 ± 2°C temperatures, 65% ± 5% relative humidity). The first step of the study was monitoring the down structure under a scanning electron microscope (Thermo Scientific Apreo S).

The thermal resistance of goose down filled test samples was tested according to ISO 11092 (British Standards Institute 1993) using an SDL ATLAS M259B Hot Plate Tester. Clo values were calculated

with the following formula by using the obtained thermal resistance values. Clo values were calculated by using 1 clo = 0.155 m^2K/W.
Air permeability tests of the samples were carried out by using a Textest-FX 3300 testing machine (pressure difference was 100 Pa, measured area was 20 cm^2) in accordance with ISO 9237 standard specifications [20]. The thickness of the samples was measured according to the relevant standards [21].

RESULTS AND DISCUSSION

The morphological structure of down feather

The first step was to determine the morphological study of the down structure under a scanning electron microscope (SEM). Figure 3 shows SEM pictures of down samples with a magnification of 1000. Figure 4 indicates the SEM pictures of gooseneck feathers magnified by 2500 times.

Air permeability

As shown in figure 5, the air permeability values of the nonwoven materials filled with 90/10 and 80/20 ratio blended down feathers were close to each other. However, when the amount of filling was examined, it was observed that the air permeability decreased as the filling amount increased. The air permeability of the sample filled with 20 g was the highest value.

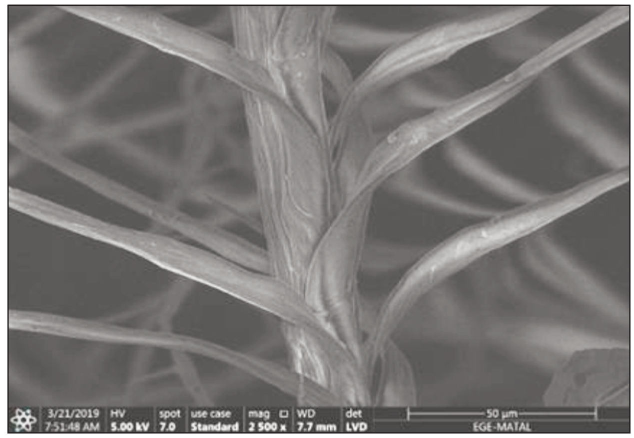

Fig. 4. SEM photo of gooseneck feathers

Thermal resistance

Figure 6 shows the thermal resistance values of the samples. The thermal resistance values were close to each other with the down ratios of 90/10 and 80/20. When the amount of filling is examined, it is seen that both the 90/10 and 80/20 ratios increase the amount of thermal resistance.
The concept of the 'clo' is a unit to measure the thermal resistance of clothing, which is called 'clothing insulation' [22]. Clo values were obtained by using the conversion equation of 1 clo = 0.155 m^2K/W. Figure 7 shows clo values of the samples.

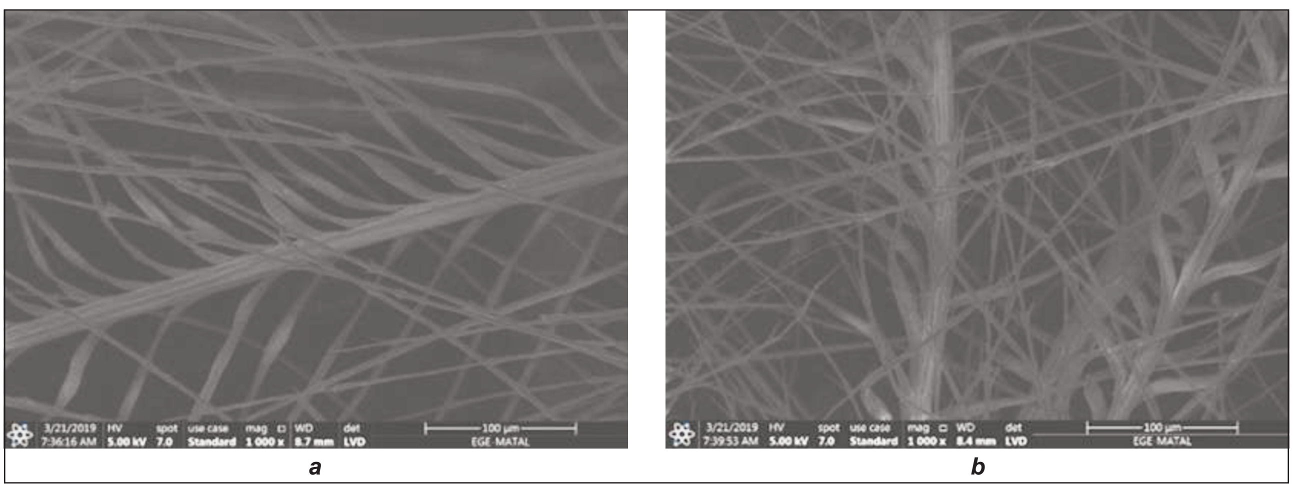

Fig. 3. SEM photos of goose down feathers: *a* – the down feather with 80/2; *b* – the down feather with 90/10

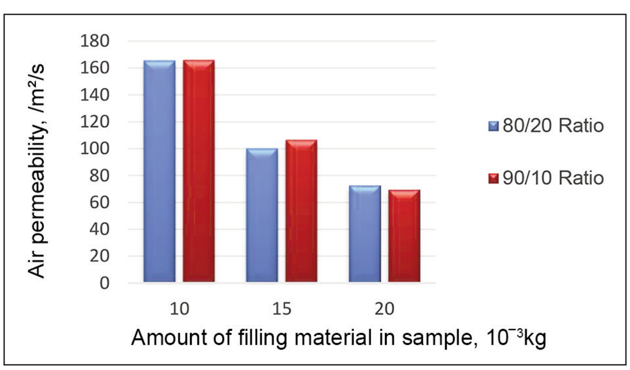

Fig. 5. Air permeability values of the samples

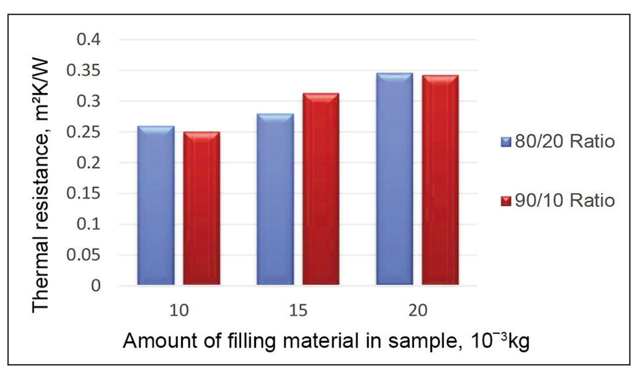

Fig. 6. Thermal resistance values of the samples

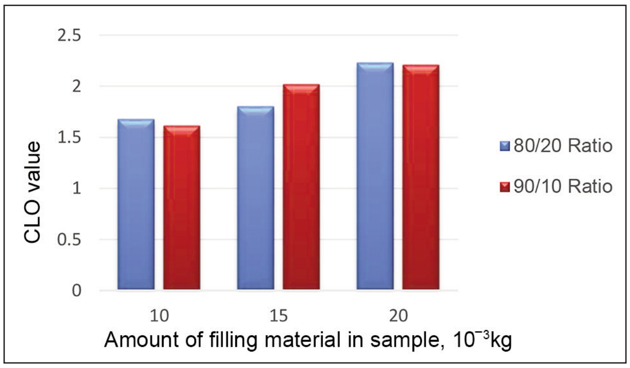

Fig. 7. Thermal insulation values of the samples in clo unit

CONCLUSIONS

The living organisms in nature have undergone various physiological changes depending on the climate and living conditions of their region. Animal fibres that support the preservation of the body temperature of the organisms living in the regions where the ambient temperature is very low contribute to the improvement of the thermal properties when used in the clothing.

In the study, goose down was used in the 90/10 and 80/20 ratios. The ratio of 90/10 indicates that softer and higher quality down are used more in the gooseneck feather. The 80/20 ratio indicates that the use of gooseneck feathers is reduced and the rate of use of wing feathers increases. The thermal resistance test of the goose down was used in the study with 90/10 and 80/20 ratios and 10 grams, 15 grams and 20 grams filling rates.

The ratios of 90/10 and 80/20 were close to each other in terms of thermal resistance and clo values. The reason for this is that they both show similar feather characteristics. However, the major disadvantage is that the end portions of the wing feathers are more pointed and that during usage they can penetrate from both the stitches and the fabric, however, the gooseneck feathers are not pointed. For this reason, although they are more expensive, customers can prefer 90/10 due to this usage comfort.

When the amount of filling is examined, it can be seen that both the 90/10 and 80/20 ratios increase the amount of thermal resistance and clo value as the filling amount increases. This can be achieved by increasing the filling quantities in the regions where different heat retention values are desired in different garment sections or the ambient temperature is too low.

As can be seen from SEM images, down clusters were made of a large number of subunits each with appropriate orientation and crotches and triangle nodes. This structure provides thermal insulation of goose feathers.

As the air permeability of the samples increases, the amount of air entering the samples also increases. This results in faster heat and moisture transfer. Therefore, the fabric with low air permeability has the highest thermal resistance. When the air permeability results of the samples were examined, it was seen that the air permeability values were close to each other filled with both 90/10 and 80/20 ratios down feathers. However, when the amount of filling was examined, it was observed that the air permeability decreased as the filling amount increased. The air permeability is inversely proportional to the amount of down. This is indicative of the insulating property of the goose down.

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