

DEVELOPMENT OF TECHNOLOGY AND MEANS OF CASHMERE DOWN PROCESSING

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Abstract

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World market the goat down in type cashmere (fineness 11-18 microns) is delivered in insignificant volumes within 5-6 thousand tons from the states of Asia: China, Mongolia, Iran, Afghanistan. The Republic of Kazakhstan has potential possibilities on production increase goat-breeding and it is predetermined as by essential growth in the conditions of market economy of goats number (to 3237.2 thousand in 2010 year in comparison with 980 thousand goals in 1991y.), and display in home market increasing demand for its production, first of all on the goat down (Razumeev, 2000; Kerven at al., 2005; www.minagri.kz).

As a result of this technology of the goat down and wool processing is developed, corresponding to the world standards and their introduction in manufacture on the basis of improvement of dehairing machine.

Key words: goat wool, coarse hair (fiber), goat down, cashmere, combed down, dehairing machine

Abbreviations and Acronyms: δ - an error; Cv - factor of a variation, %; L_{cp} - average length; $L_{пред}$ - length limits; F_{cp} - average fineness; $F_{пред}$ - fineness limits

Introduction

Now in the world 236 breeds of goats, including (in percentage): in Europe – 40.2, Asia – 43.7, Africa – 11.9, America and Oceania – 4.2. In a direction of the basic efficiency of breed were distributed as follows (in percentage): wool – 3.4, dairy – 34.7, meat – 12.7, downy – 8.1, meat-wool and wool-meat – 8.5, meat-wool-dairy – 8.9, dairy-meat-18.6, park – 0.4, meat-leather-pack – 2.6 (www.kozaprom.ru).

The big interest in the world causes the goat down. The goat down is the most thin kind of a fiber of an animal origin and characterize by good spinning properties, felting quality, ease, elasticity, relative durability and small heat conductivity. Now the goat down subdivides into two types. Cashmere is down of goats with heterogeneous wool in the fineness of fibers to 19 microns. Kazhgorsky is down in the fineness of fibers more than 19 microns, received from mixed animals at crossing down with wool goats breeds. This kind of production of goats represents special category wool raw materials. The down is

more fine Merino wool, and products from it possess ease, softness, and beauty. The physical properties of down have essential value at its technological processing, the fineness, length, a strength fortress, elasticity, fluffy up ability. Cashmere is an outstanding representative of goat down. He has the fine fiber, rather short, fine curve, very strong, 11-18 microns in diameter and a length of 4-10 cm. This down is special, so-called Cashmere breed of goats. Cashmere characterized by good spinning properties, ease, elasticity, durability, small heat conductivity. Fine high-quality jersey, the best grades of hat felt and coat produce from cashmere (Phan and Wortmann, 2000; McGregor and Butler, 2008; Lecraw, 2007).

Down goats in Kazakhstan is about 1.6 million ones and it is annually made 270 ton down, including 120 ton the Cashmere. Cashmere down receives from the local native goats who have not affected cultural breeds. They are bred mainly in the southern, south-western and western regions. Kazakh down on the quality indicators is slightly inferior to the Mongolian down. According to the employee of laboratory on

testing fibers Hilary Redden (the United Kingdom) the Cashmere down of Kazakhstan has considerable variations of a fineness of fibers on regions from 15.4 to 17.3 microns. Now the goat down is bought, basically, the Chinese suppliers and, the down most part is taken out in not processed kind under the low prices (Redden, 2007).

Currently goat down is purchased mainly by Chinese suppliers and, most part is exported as raw materials on low prices (Redden, 2007).

Materials and Methods

Selection technique of the goat wool

To obtain higher profitability from the goat down processing we conducted research aimed at developing primary processing of goat down and production technology, including purchase, classifying, scouring, dehairing (removal of down from coarse fibers) of raw wool.

In total the goat down has been purchased in amount volume of 1860 kg from southern regions of Kazakhstan (Kyzylorda and South Kazakhstan areas). From this quantity of 1265 kg, or 68% the down has been carried to down to I class, supposing the maintenance coarse fibers to 10%. The

others of 595 kg, or 32% - II class, where a limit on the given indicator is to 20%. The down on colour is carried, basically, to coloured, and the yield of white colour has made 340 kg, or 18.3%.

Results resorting given volume down, we conducted in accordance with Interstate Standard of RK 2260-2006 (Table 1) found that only 176.8 kg or 9.5% is the standard combed down. The remaining 90.5% goat down purchased from sheared wool followed by manual separation down from the coarse wool (Interstate Standard, 2006). As a result of this volume with a total mass of 1683.2 kg classified as Down Class IV with high content the coarse wool (40%). Its processing is possible only on enterprises with a set of goat wool dehairing equipment.

Purchase results of the specified lot of the goat down precede from purchase practice the given raw materials, developed on Kazakhstani domestic market. In particular, there is an interest in the purchase of not combed down and down mixed with fibers as sheared wool and then export to foreign countries, especially in China, where it is reprocessed with the separation down from the coarse fibers (Fan, 2007; Aryngaziev, 1998). The given form of preparation does not create a interest for farmers in combed down production as

Table 1
Results of classifying the goat down

Indicator	Purchase standard		Industrial standard	
	Kg	%		Kg
Classified down, kg	1860	100	176.7	100
Method of preparation of down:				
- IV class	1683.2	90.5		
- combed including:	176.7*	9.5*	-	
- I class	91.2	51.6	-	
- class II	85.5	48.4		
Condition:				
- normal	24.0	13.6	-	
- weed	152.7	84.4	-	
Colour:				
-white	50.0	28.3	-	
-light grey	36.6	20.7	-	
-coloured	90.1	51.0	-	
Name:				
-combed down*	176.7	100.0	-	
Fineness:				
- up to 17 um	-		157.3	89.0
-18 um and coarser	-		19.4	11.0
Length:				
-30 mm and above	-		152.9	86.5
-25 mm and lower	-		23.8	13.5

* - following classifying an all indicators of the standard is spent on carded down with weight 176.7 kg

the offered prices on it are very low and not correspond to the world prices (about 10-20 US dollars for 1 kg). In converting on one goat these prices are almost equivalent down realisation in a mix with coarse fibers in a kind of sheared wool realised on US dollars 2.7-3.4 kg per 1 kg (the clip from 1 goat makes about 0.5 kg, and the content in it of down, on the average, 0.15 kg or 30%) (Figure 1).

Based on the foregoing, the further research of technology of goat down processing was spent on down volume with weight 176.7 kg, and its classifying results on all indicators of purchase and industrial standards are given in Table 1.

The down prepared in the way of goats comb, i.e. combed down, also was characterised by the low content of coarse fibers and has been carried to Down Class I. So, raw materials with content of coarse fibers to 10% are 91.2 kg, or 51.6%. And the others of 85.5 kg, or 48.4% had level of the undesirable fibers in limits from 10 to 20% and, thereby, the given weight corresponded to requirements of raw materials of Down Class II. This is the result of late comb of goats, i.e. its not making in the initial period of a down moult. In much later date the fibers felt and kept in wool tufts in a mixture with coarse fibers, so separating the down form the coarse fibers in this condition becomes more difficult.

The sorted down was excessively vegetable and mineral impurities and, thus, 84.4% or 152.7 kg, as related to dirt down. Only 13.6% or 24.0 kg down confirmed the requirement of normal down - less than 1.5% of the total weight. It is also a result of non-observance by farmers the comb technology, i.e. making it in a certain period and cleaning combed down from vegetable and mineral impurities.

The impurity content depends on the down grade, i.e. on the content of coarse fibers. Thus, Down Class I has the smallest the content impurities, and the down was average

3.5%, Down Class II was 9.7% and the Down Class IV was 14.8%. This is quite natural, since the felt down remains more impurities and it is separated difficult.

According to the classifying results 157.3 kg or 89.0% of the raw materials with a fineness of 17 microns were high quality of Kazakh coarse wool (down) goats. It satisfies the requirements of fine-fiber down of the type Cashmere, which is most deficiency in the world market. This volume of down also satisfies the processing industry of foreign countries, such as Mongolia and the United Kingdom (length down in these countries should be at least 28 mm). Length of Kazakhstanian down was more than 30 mm in 86.5% of the total weight of classified raw materials (Redden, 2007; Fan, 2007). Classified down weight with length of 25 mm was 23.8 kg or 13.5%. This down was probably purchased from sheared wool, giving of down shortness as a result its second clip.

We set high enough yield the desired light-coloured down - light gray was 36.6 kg and white was 50.0 kg, or 20.7 and 28.3%. Specific weight of coloured down (light and dark brown) was 51% or 90.1 kg.

For a more focused research purchased down quality we investigated the fineness and the curve depending on the purchase (Table 2), and the length and the fineness depending on its colour (Table 3).

Found that the smallest fineness, and thus, the best equation is typical for the raw material in the form of combed down: 17.95 μm with a coefficient of variation of 32.2% (Down Class I), 22.39 μm and 67.50% (Down Class II) and 29.75 μm and 73.48% (Down Class IV), purchased by sheared wool. Difference, respectively, in fineness - 11.8 μm and 7.36 μm , coefficient of variation - 41.28% and 5.98%.

These research results allow to conclude that in the theoretical aspect of the financial expenses of the complete sepa-

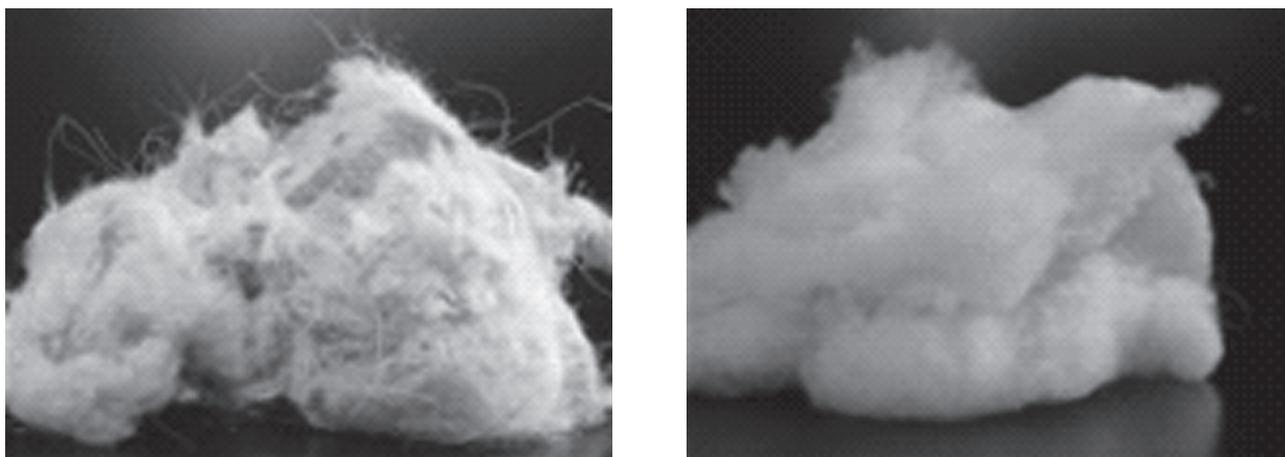


Fig. 1. The goat wool: a) before down processing and b) after scouring and dehairing process

ration of down from coarse fibers at the corresponding equipment during their further processing will be significantly lower down purchased by combing method, i.e. raw material, having the smallest content of undesirable coarse fibers. A similar difference in the fineness of the raw material in a mixture with coarse fibers concerning the fineness of the basic type fibers (down), is significantly lower than Down Class IV: 14.0 times Down Class I and 2.3 times Down Class II.

Characterizing the prepared raw duvet regarding its further processing to complete separation from spine, it should also be noted that they are available in coarse fiber length (82.1 mm, Table 3) comply with the prescriptions of equipment for dehairing goat wool, where the limit for this indicator is 100 mm, the longer the guard fibers are wound on the teeth, which leads to breakage as they contain feather fibers and forced stop operation.

In general, the sorted down, though was of poor quality content of coarse fibers, vegetable and mineral impurities, but by other parameters confirmed the worldwide market requirements: length - 45.1 mm, fineness - 16.25 microns.

Down of light colour, including white, on the main physical and mechanical properties had no significant differences with the less valuable colored down (Table 3).

According to one of the best foreign analogues - Mongolian goat down corresponding indicators are: fineness is 16.2 um, standard deviation is 3.34 um, length - 40-50 mm, high content of short fibers up to 30 mm - 16.1% (Interstate Standard 2260-2006).

These mechanical properties of the Kazakh coarse wool (down) goats indicate its quality to the best foreign analogues and the down delivery possibility, along with the processing inside the country and exported directly from the country, and not through other foreign countries, as it is practiced nowadays.

Scientific experiments on dehairing down

We conducted experimental tests on dehairing down Class IV of Kazakhstani goats from coarse fibers held in a special flat carding machine for down cleaning FN 288 C, Company Qingdao Yuan Quan Textile Machinery Factory CO., LTD (China). The essence of the process of cleaning the goat

Table 2
Average fineness and curve the goat down depending on ways of purchase

Down Class	Way of purchase	Fineness, a micron			Curve, degree/mm
		F	δ	Cv, %	
I – content of coarse fibers to 10%	Combed down, including down	17.95	5.43	32.2	64.5
		16.89	3.46	21.8	67.1
	Difference:				
	um	1.06	-	-	-
%	6.2	-	-	-	
II - content of coarse fibers to 20%	Combed down, including down	22.39	15.58	67.50	53.38
		16.06	3.18	19.83	59.50
	Difference:				
	um	6.33	-	-	-
%	39.4	-	-	-	
IV - content of coarse fibers over 40%	Sheared wool with partial manual coarse fibers separating, including, down	29.75	21.78	73.48	41.47
		14.97	3.05	20.43	61.0
	Difference:				
	um	14.78	-	-	-
%	98.7	-	-	-	

Table 3
Length and fineness the basic types of fibers in combed down, depending on its colour

Down colour	Down length, mm		Coarse wool length, mm		Down fineness, a micron	
	L _{ср}	L _{пред}	L _{ср}	L _{пред}	F _{ср}	F _{пред}
White	50.0	33-69	79.8	57-103	16.45	14.9-20.0
Light grey	40.4	33-55	73.0	58-84	15.43	13.4-18.8
Colour	43.8	28-84	87.0	59-111	16.45	14.0-22.4
Average	45.1	28-84	82.1	57-111	16.25	13.4-22.4

down from coarse hair on this equipment is its sorting fiber by hardness. Goat wool, consisting of down and coarse fibers, is captured by card fillet drum. Down fibers due to the low hardness penetrate mostly between card fitting needles. And the coarse fibers due to the greater hardness mostly come out above the surface of the card fitting and are exposed knives and sticks blow. As a result, small tenacity and slack capture by the card fillet the coarse fibers separate at blow from the main mass and fall down under the machine.

For down processing we prepared experimental lot of goat wool in volume 137 kg. Prior scouring was at 4 baths, using washing powder "Laska" of Company "Henkel ERA" (Russia). Yield in scouring was 82%. On the quality of match Down Class IV and on the content as Dirty down in accordance with the requirements of Interstate Standard 2260-2006. Content of the coarse hair was 22.7%, dandruff - 4.5% and vegetable matter - 4.5%.

The cleaning was carried out on machine in a few transitions for high-quality dehairing down.

Mechanical down sorting to fractions of fiber types based on their combing, separation and straightening has an impact on physical and mechanical properties of down (Tables 4, 5 and 6).

Substantiation of fibers sorting by combed drum based on the probability of rupture

Wool carding process is the most important in the system of spinning wool. It significantly affects the yield and quality parameters of yarn. Mathematical model of sorting wool fibers allows predicting the properties of the effluent, to assess the impact of input factors, develop a scheme of control and management of the most highly influencing factors.

Currently known and used a hypothetical model of sorting wool fibers (Bitus, 2007). Model is obtained taking into

Table 4
Change of qualitative structure of the goat down of Class IV on fractions of fiber types, vegetable matter content in dehairing process

Frequency rate of goat down processing on scutcher machine	Content, in %			
	Down	Coarse fibres	Dandruff	Vegetable matter
Before enter for processing	82.4	14.4	1.6	1.6
After one-time processing	93.0	6.6	0.4	0.0
After triple processing	98.4	1.4	0.2	0.0
After fivefold processing	99.6	0.4	0.0	0.0
After eightfold processing	99.8	0.2	0.0	0.0

Table 5
Change of goat down length of Class IV in dehairing process

Frequency rate of processing	True length of down, mm				
	M±m	δ	Cv	In relation to initial length	
	mm		%	mm	%
Before enter for processing	42.9±0.580	14.21	33.1	0	100,0
After one-time processing	40.8±0.616	15,10	37.0	-2.1	95.1
After triple processing	36.6±0.674	16.50	45.0	-6.3	85.3
After fivefold processing	32.4±0.478	11.70	26.1	-10.5	75.5

Table 6
Change of fineness the goat down of IV length in dehairing process

Frequency rate of processing	Down fineness, a micron				
	M±m	δ	Cv	In relation to initial fineness	
	Micron		%	Micron	%
Before enter for processing	16.7±0.084	4.20	25.5	0	100,0
After one-time processing	15.9±0.075	3.73	23.5	-0.8	95,2
After triple processing	15.6±0.065	3.26	20.9	-1.1	93,4
After fivefold processing	15.5±0.066	3.31	21.4	-1.2	92,8

account the differential law of the fibers distribution along their length in the feed product, the main filling parameters of carding machine and design features of carding machine for wool (1).

$$\omega_1(L) = \begin{cases} 0, & \text{при } 0 < L \leq L_c - l_n \\ \omega(L) \cdot (L + \lambda_n - L_c) / \lambda_n, & \text{при } L_c - l_n < L \leq L_c \\ \omega(L), & \text{при } L_c < L < L_{\max}, \end{cases} \quad (1)$$

where: L - average length of woolen fibers, mm; L_c - zone of fibers sorting on length; l_n - supply length; $\omega(L)$ - the differential law of distribution of fibers on length (DLDFL) in a product arriving in the carding machine; $\omega_1(L)$ - DLDFL, in dehairing wool. L_{\max} - maximum length of the fibers in a tape.

Mathematical model of sorting combed drum based on the probability of fiber breakage is implemented on a computer in the MS Excel.

Then we carried out calculation of ordinates of differential function of fibers distribution on their length - $\omega_1(L)$ after combed by card drum with due regard for their rupture and calculation of numerical characteristics of fibers distribution in a feeding tape - $\omega_0(L)$ and in carding tape - $\omega_2(L)$. Results also can be received in the form of integrated or differential curves of fibers distribution on their length before and after carding. On the basis of the developed model of sorting and its computer algorithms we develop in the environment of Microsoft Excel the multicriteria optimization carding process in the presence of restrictions. The problem of conditional optimization solved by means of the subprogram «Decision Search», using the algorithm of nonlinear optimization Generalized Reduced Gradient (GRG) developed by Leon S. Lasdon (University of Texas at Austin), the modified method of the interfaced gradients (Bitus, 2003, Bitus, 2007, Sevostyanov, 2007). By the given multidimensional optimization private derivatives of criterion function - $F(x_1, x_2, x_3)$ (2) were calculated not analytically, by numerical differentiation methods.

$$F(x_1=L_c; x_2=l_n; x_3=Vb) = L_{cp} \max \quad (2)$$

Dehairing process improvement opportunities

Many textile workers are interested how on carding equipment, possibly with minimum material expenses, to get a good quality semi-finished product, to save raw materials and to provide longer life carding fitting; which modern fitting types should be placed on those or other designs of carding machines in the processing of diverse mixtures of fibers having high content of impurities, etc.

Often the fitting installed on the equipment that recommended by 20 or more years ago. Enterprises do not consider a raw material change, content of impurities, equipment opportunity to work at different speeds and so on. Modern development in the world of engineering and technology textile machinery led to significant advances designs carding machines and used carding fitting.

Solution on many textile enterprises of current crisis is the equipment modernization. Modernization of rolling carding equipment may be directed as at improving the accuracy of drums and rollers, replacing older types on the modern fitting and the installation of additional devices: vibrocombs, dirty shelves with chops rollers of modern designs, pressing shafts and units for cleaning wool (Lasdon at al., 1996).

A device was known, where combed fiber from a main drum passes to the doffer drum. Carded batting from the main drum removed by roller picking and passed through the pressing rollers (Bukaev, 1987).

Also known dehairing machine described by E. Oyuunzayaa, where carding and accompanying processes are carried out in the areas of interaction of the main drum and removable rollers (Ojuunzajaa, 2005). Needle of removable roller inclined in the direction of working roller rotation, therefore, the removable roller continuously removes fibers from the worker roller and transfers them to the main drum, where the addition and mixing of the two streams.

The disadvantage of these machines is that a large percentage of the coarse fibers content in the down.

There is also a device of Klimanov at al. (1973). He converted the single-drum carding machines, interconnected plate conveyors. A distinctive feature of his invention is that three combed rollers set on conventional roller carding machine over the main drum. Surfaces of these combed rollers are covered with needle tapes. Needle inclination provides the ability to capture from the drum surface the protruded coarse fibers. The distance between the drum needles and the surface combed rollers needles can be varied from 5 to 12 mm, depending on the kind and sort of processed wool. Removal of coarse and dead fibers with needles of rollers combed fitting is made by removable rollers with long flexible needles, which ends a few come into the space between the needles combed roller. Further removal of fine fibers produced two top combed rollers installed under removable drum.

The disadvantage of this device is that the length of the coarse hair is preserved and coarse fibers removal process is slow and unproductive. Our task was to develop an optimal mechanism for the removal of long coarse fibers.

Dehairing machine operates as follows (Otyunshiev and Imasheva, 2010). From the receiving drum wool comes to

main drum 1, covered with serrated or needle tape, as shown in Figures 2 and 3.

The basic process occurs between the main drum and flats (rollers). Combed fibers are transferred from the main drum to a removable drum 2. Cutting edge between the fixed blade 3 and the cutting edge of the spiral blade 4 with action, like scissors, cut the protruding course from splitting fitting of doffer drum. Setting between the stationary knife surface and doffer drum fitting is adjusted depending on the wool type. Then the wool into thin wadding took by the removed comb. The remainders of the coarse fibers in the doffer drum fitting with down passed and removed at the next dehairing stages.

Down cleaning efficiency (yield percentage) from coarse fibers increased for $45\pm 5\%$, with a 10% decreased the loss spinnable fibers in waste. Thus, the content of coarse fibers with a length of 100 mm reduces at $85\pm 5\%$.

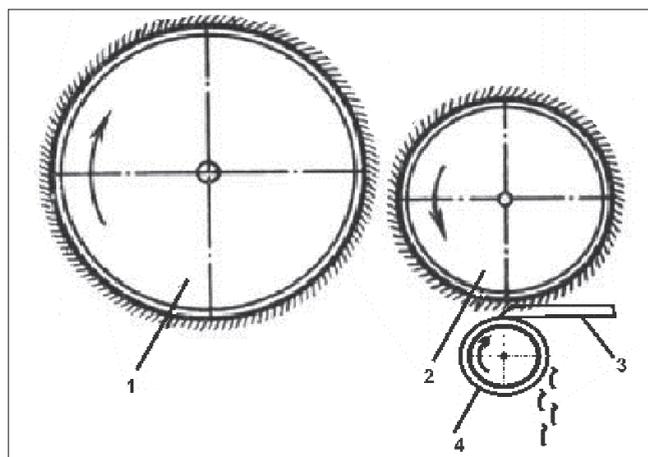


Fig. 2. General view of process of wool (canvas) transition from the main drum on a doffer drum

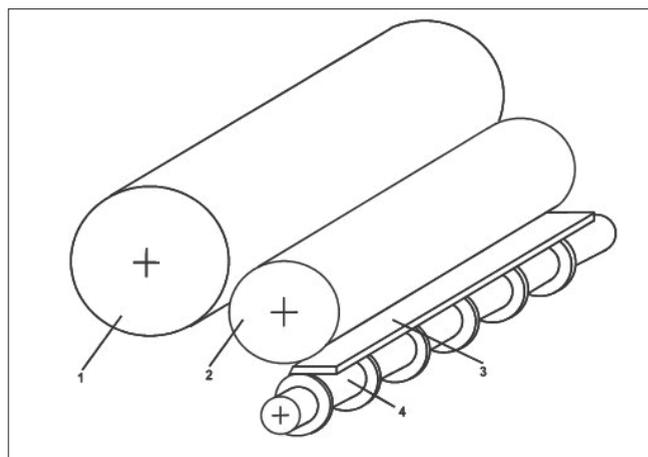


Fig. 3. 3D-view of the combing wool process

Results and Analysis

Results of experimental research of qualitative composition of goat down of Class IV on fiber type fractions and the content of impurities in the dehairing process, shown in Table 4.

The existing vegetable matter in down removed completely after one-time processing, and a dandruff - after triple processing. And the existing vegetable matter the coarse fibers is only achieved after eightfold processing. The bulk of coarse fibers separated from one-time to triple processing, reducing a specific weight from 14.4% to 1.4%. Or 13.0%, and by subsequent (from fourfold to eightfold) processing achieved a decrease in its share of only 1.2% or 1.4% to 0.2%. Coarse fibers content to 1% conform the Cashmere Standard and, thus, optimal parameter to achieving required down quality is sufficient the fivefold processing.

The difficulty in separation the coarse fibers and the resulting eightfold down processing in dehairing machine led to a partial deterioration of certain physic-mechanical properties of the down, in particular its length. The results of the length changing of the goat down Class IV during dehairing process shown in Table 5.

The initial down length, i.e. before entering processing was 42.9 mm and the qualification requirements of the Chinese market was consistent long-fiber down (36-40 mm), the estimated cost 65-75 % higher than the short-fiber /10/. From the results it is seen that the true down length after each processing decreased even at fivefold processing and attained a necessary length for woolen yarns production, i.e. $M\pm m-36.6\pm 0.674$; $\delta - 16.5$; $Cv - 45$, respectively, further processing does not require.

In the process of down machine dehairing from the coarse fibers its average true length decreased with each pass and the overall decline was 10.5 mm or 25.5%, including between the six fold to eightfold processing - from 36.6 to 32.4 mm, and thus reached the short down level. Goat down fineness changes of IV length in dehairing process are shown in Table 6.

During processing the average fibers fineness decreased at 1.19 micrometer or 7.28 % (Table 6).

Thinning of the down fibers on the first three passes was 0.80 m or 4.8%, and for the last three passes, from the fifth to the eighth, again decreased by 0.40 m or 2.4%. Reducing down fineness to be regarded as a consequence of a decrease in the specific content of long fiber down fraction, is an intermediate fiber types with higher fineness.

In general, the results of the experiment showed that during the action of the scutcher machine in the down processing, along with the loss of coarse fibers and impurities, there is a partial change of physic-mechanical properties of down fibers. When combing breakage occurs his long-fiber frac-

tions and loss shortened fibers. As a result, some quality indicators improved (uniformity of fiber length, thinning). But significantly the length decreases to below the desired short fiber down. Moreover, not all long-fiber fraction length more than 100 mm is removed completely.

Conclusion

The research found that:

- Average fineness down of the Kazakhstan down goats is in limits 15-18 microns. Therefore, the down of the Kazakhstan down goats after appropriate preparation can be carried to Cashmere down on the international classification.
- Shortening of average down fibres length makes 14.7% in dehairing process the Kazakhstan heterogeneous wool from coarse fibers and dirt on flat combing machine FN 288 C, Company Qingdao Yuan Quan Textile Machinery Factory CO., LTD (People's Republic of China). The average length of down fibres after fivefold processing by machine FN 288 C makes 15.6 ± 0.065 mm, variation factor on length is 20.9%.
- No more 5 multiple processing on FN 288 C is necessary for getting of characteristics on down length of the international standards.
- Offered improved dehairing machine with the additional mechanism for removal of long coarse fibers can improve the cleaning of down from coarse hair by $45 \pm 5\%$, while reducing by 10% the loss of spinnable fibers in the waste, and reduce by $85 \pm 5\%$ content of coarse fibers with length more than 100 mm.

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