FOUR FACTOR ANALYSIS OF VARIANCE OF FIBRE DIAMETER

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ABSTRACT

As for the research methodology, we used sample of cashmere of goats, from some soums of Khentii province. We formulated the definition that is expressed by the values of different experiments of 4 factor analysis of variance. When we calculated, we used the formulation of 4 factor analysis of variance.
Fibre diameter of goats of Khentii aimag that went under the research fluctuated between 13.70-18.10 μm, average was 115.63±0.005μm; female goats` fibre diameter fluctuated between 13.7-18.10 μm and average was 15.66±0.13 μm; while male goats` fibre diameter fluctuated between 13.8-17.40 μm and average was 15.60±0.005 μm. Fibre length of goats that went under the research fluctuated between 3.57-7.13 μm; average was 5.13±0.004 cm; female goats` fibre length fluctuated between 3.73-7.00 cm and average was 5.01±0.005; while male goats` fibre length fluctuated between 3.57-7.13cm and average was 5.23±0.004cm.
In terms of the percentage of effects of each factor: the factor "Soum"`s effect percentage was 2.5%, and the effect percentage of the factor "Goat sex" was 1.23%, factor "Goat age" was 59.1%, and factor "Fibre length" was 20.14%, and factor "inter-reaction of all factors"`s effect percentage was 16.33%. Among these factors the strongest effect factor was the goat`s age.

INTRODUCTION

According to the livestock census at the end of 2014 in our country, there were 51.9 million livestock were recorded, out of which 22.0 million were goats covering 42.4% of total livestock, and 6600 tons of cashmere is produced per year on average. Also, 26.8% of Mongolia`s export income comes from wool and cashmere products, and in which cashmere products cover 12%. Cashmere products are value added export products representing Mongolia.

The goat researchers team of Livestock Scientific Research Institute has been conducting a research to define cashmere quality level of the goats of selective strains, breeds and parts of breed in Mongolia and to create database since 1991. And follow up breeding and selection attempts to create a nuclear group of selective strain and breeds of goats were made on the basis of the results of the above mentioned research. As a result of these attempts, some strains have grown to independent breed.

As for the selection and breeding activities that were aimed to determine cashmere quality of the selected goats and to improve the economic productivity indicators of the goats, only selection efficiency calculation method has been used ever for breeding and selection operation. Also, 2-factor analysis of variance to identify the impact of one factor on any of the quality indicators was carried out, however, 3-4 factor analysis was not conducted. Also, the

calculation of interaction of many factors gets more complicated as the number of the factors increase. Therefore, we carried out this research with an aim to determine whether age, sex, geography or other interactions have influence on fibre diameter, the main quality indicator of cashmere, and to define which factor influence most.

METHODOLOGY

As for the research methodology, we used sample of cashmere of female and male goats of ages 1-5, from Norovlin, Galshir, Bayan-Ovoo soums of Khentii province, and we used methods of sampling, straightening lenght of cashmere fibre length, and fibre diameter was calculated by microscope of Projectina and was defined by computer calculation with scale of 10000 micrometer with support of Summaskitch-III table. Statistics groupping method, normal distribution law analyzer method were used. Also, after formulating the definition that is expressed by the values of diffirent experiments of 4 factor analysis of variance, we used 4 factor analysis of variance method.

The aim and objectives of the research. The following objectives have been set under the scope of the aim to define effect of geographic location, length and sex on fibre diameter:
- Define the indicators such as, fibre diameter and length
- Establish an interval distribution chain of fibre diameter and length
- Establish discreet distribution chain of the parameters such as, geographic location and age

Conduct 4 factor analysis of variance to determine effect of geographic location, length, age and sex of goats on fibre diameter.

RESULTS

Today, overgrazing has become a crucial issue, therefore it is a priority aim to increase the output and quality of livestock products or unit economic productivity.

Especially, we assume it is vital to determine the factors that have effect on cashmere-the in exhaustive resource and its production even though cashmere products cover small percentage of export.
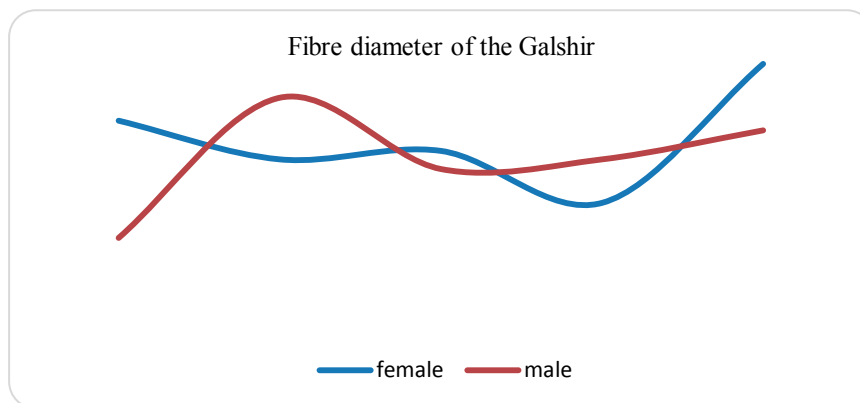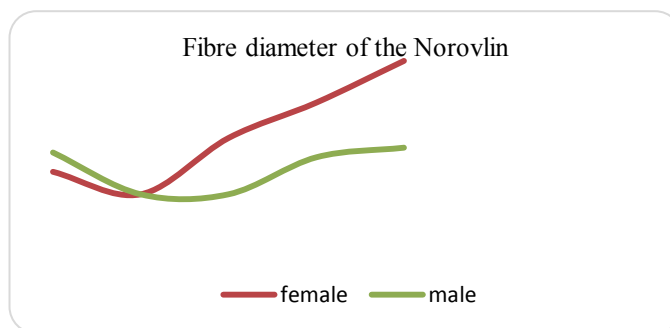

Picture 1. Fibre diameter and length, Galshir

Fibre diameter of Galshir soum fluctuated between 13.87-17.55 μm, average was 15.50±0.007 μm; female goats` fibre diameter fluctuated between 13.87-17.55μm and average was 15.63±0.016μm; while male goats` fibre diameter fluctuated between 13.90-16.88μm and average was 15.38±0.014 μm.
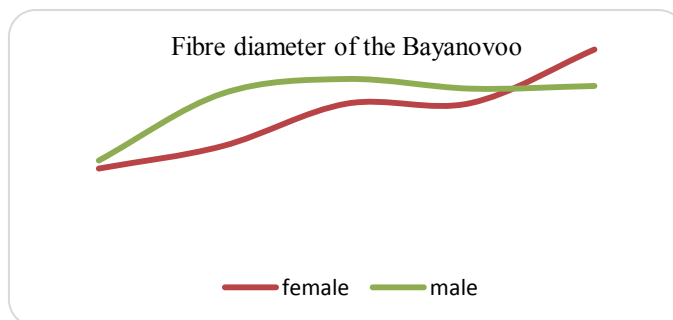
Picture 2. Fibre diameter and length, Bayanovoo

Fibre diameter of Bayan-Ovoo soum fluctuated between 13.7-18.1 μm, average was 15.76±0.009 μm; female goats` fibre diameter fluctuated between 13.7-18.1 μm and average was 15.61±0.019 μm; while male goats` fibre diameter fluctuated between 14.1-17.4 μm and average was 15.9±0.016 μm.

Picture 3. Fibre diameter and length, Norovlin

Fibre diameter of Norovlin soum fluctuated between 13.8-17.2 μm, average was 15.62±0.006 μm; female goats` fibre diameter fluctuated between 14.4-17.2 μm and average was 15.75±0.014μm; while male goats` fibre diameter fluctuated between 13.8-16.6 μm and average was 15.52±0.011μm.

Table 1

Fibre legth of the Galshar, Bayanovoo and Norovlin

Sex	Age	Galshar		Bayanovoo		Norovlin	
		Mean	Limit	Mean	Limit	Mean	Limit
Female	1	5.24±0.09	3.73-7.0	4.80±0.07	4.17-5.17	5.13±0.05	4.81-5.64
	2	5.12±0.05	4.40-5.93	4.64±0.05	3.86-6.00	5.10±0.15	3.87-6.36
	3	5.00±0.06	3.83-5.80	4.37±0.04	3.83-4.93	5.03±0.03	4.43-5.94
	4	5.50±0.08	4.83-6.77	4.83±0.05	4.29-5.83	5.16±0.05	4.58-6.23
	5	5.16±0.10	4.49-6.07	4.94±0.04	4.30-5.60	5.46±0.08	4.93-6.32
	Average	**5.19±0.015**	**3.73-7.00**	**4.71±0.011**	**3.80-6.00**	**5.15±0.011**	**3.87-6.36**
Male	1	5.08±0.04	3.97-6.14	4.23±0.16	3.76-4.57	5.16±0.10	4.49-5.99
	2	5.68±0.06	3.07-6.27	5.06±0.07	3.57-6.60	5.47±0.03	4.68-6.05
	3	5.31±0.07	4.57-6.90	5.07±0.06	4.27-5.93	5.35±0.03	5.06-6.08
	4	5.10±0.07	3.90-6.50	5.12±0.05	4.20-6.07	5.41±0.03	4.83-6.17
	5	5.99±0.16	4.23-7.13	5.11±0.06	4.07-6.83	5.28±0.03	4.81-6.04
	Average	**5.33±0.015**	**3.90-7.13**	**5.02±0.014**	**3.57-6.83**	**5.31±0.007**	**4.49-6.17**

Fibre length of Galshar soum fluctuated between 3.73-7.13 cm, average was 5.27±0.007 cm, fibre length of Bayan-Ovoo soum fluctuated between 3.57-6.83 cm, average was 4.87±0.006 cm, fibre length of Norovlin soum fluctuated between 3.87-6.36cm, average was 5.24±0.005cm.

Four factor analysis of variance formula definition

Varies of n_i number of experiments were done on each pair of non-dependent and inter-dependent (i, j, k, d) levels and then the main equation of the 4 factor analysis of variance would be:

$$Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$$

Here:

Q_1 is sum of quadrates that evaluate effects of A factor

Q_2 is sum of quadrates that evaluate effects of B factor

Q_3 is sum of quadrates that evaluate effects of C factor

Q_4 is sum of quadrates that evaluate effects of D factor

Q_5 is sum of quadrates that evaluate inter-dependence of the factors A, B, C, D factors

Q_6 is sum of quadrates that evaluate effects of other factors. General average was:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{r}\sum_{j=1}^{u}\sum_{k=1}^{v}\sum_{d=1}^{g}\sum_{s=1}^{e} x_{ijkds}$$

The average value of paralel experiments made on each pair of level (i, j, k, d):

$$\bar{x}_{ijkd*} = \frac{1}{n_s}\sum_{s=1}^{e} x_{ijkds}$$

The average value for A factor:

$$\bar{x}_{i****} = x_{ijkd*}$$
$$= \frac{1}{n_i}\frac{1}{n_j}\frac{1}{n_k}\frac{1}{n_d}\left(\sum_{i=1}^{r}\sum_{j=1}^{u}\sum_{k=1}^{v}\sum_{d=1}^{g} x_{ijkd*}\right)$$

The average value for B factor:

$$\bar{x}_{*j***} = x_{*jkd*} = \frac{1}{n_j}\frac{1}{n_k}\frac{1}{n_d}\left(\sum_{j=1}^{u}\sum_{k=1}^{v}\sum_{d=1}^{g} x_{*jkd*}\right)$$

The average value for C factor:

$$\bar{x}_{**k**} = x_{**kd*} = \frac{1}{n_k}\frac{1}{n_d}\left(\sum_{k=1}^{v}\sum_{d=1}^{g} x_{**kd*}\right)$$

The average value for D factor:

$$\bar{x}_{***d*} = x_{***d*} = \frac{1}{n_d}\left(\sum_{d=1}^{g} x_{***d*}\right)$$

Table 2

Evaluations of corresponding variance and degree of freedom are shown in the table below:

Disperse	Sum of quadrates	Degree of freedom	Disperse evaluation
A factor	$Q_1 = n_{i****}\sum_{i=1}^{r}(\bar{x}_{i****} - \bar{X})^2$	$(u-1)(v-1)(g-1)$	$S_1^2 = \dfrac{Q_1}{(u-1)(v-1)(g-1)}$
B factor	$Q_2 = n_{*j***}\sum_{j=1}^{u}(\bar{x}_{*j***} - \bar{X})^2$	$(r-1)(v-1)(g-1)$	$S_2^2 = \dfrac{Q_2}{(r-1)(v-1)(g-1)}$
C factor	$Q_3 = n_{**k**}\sum_{k=1}^{v}(\bar{x}_{**k**} - \bar{X})^2$	$(r-1)(u-1)(g-1)$	$S_3^2 = \dfrac{Q_3}{(r-1)(u-1)(g-1)}$
D factor	$Q_4 = n_{***d*}\sum_{d=1}^{g}(\bar{x}_{***d*} - \bar{X})^2$	$(r-1)(u-1)(v-1)$	$S_4^2 = \dfrac{Q_4}{(r-1)(u-1)(v-1)}$
Interaction	$Q_5 = n_{ijkd}\sum_{i=1}^{r}\sum_{j=1}^{u}\sum_{k=1}^{v}\sum_{d=1}^{g}(\bar{x}_{ijkd*} - \bar{x}_{ijk**} - \bar{x}_{ij*d*} - \bar{x}_{*jkd*} - \cdots \bar{x}_{i****} - \cdots + \bar{X})^2$	$(r-1)(u-1)(v-1)(g-1)$	$S_5^2 = \dfrac{Q_5}{(r-1)(u-1)(v-1)(g-1)}$
Remainder	$Q_6 = \sum_{i=1}^{r}\sum_{j=1}^{u}\sum_{k=1}^{v}\sum_{d=1}^{g}\sum_{s=1}^{e}(x_{ijkds} - \bar{x}_{ijkd*})^2$	$\sum n_{ijkds} - ruvg$	$S_6^2 = \dfrac{Q_6}{\sum n_{ijkd} - ruvg}$
General	$Q = \sum_{i=1}^{r}\sum_{j=1}^{u}\sum_{k=1}^{v}\sum_{d=1}^{g}\sum_{s=1}^{e}(x_{ijkds} - \bar{X})^2$	$\sum n_{ijkde} - 1$	$S^2 = \dfrac{Q}{\sum n - 1}$

$$F_A = \frac{S_1}{S_6} \qquad F_B = \frac{S_2}{S_6}, \qquad F_C = \frac{S_3}{S_6}, \qquad F_D = \frac{S_4}{S_6}, \qquad F_{ABCD} = \frac{S_5}{S_6}$$

Table 3

Calculation of the averages for 4 factors

Soum	Sex	Age	Fibre length			
			2.97-4.17	4.17-5.37	5.37-6.57	6.57-7.77
Galshir	Male	1	14.06	14.69	15.374	
		2		16.1	15.996	
		3		15.39	15.493	
		4		15.25	15.97	
		5		16.03	15.34	15.85
	Femal	1	15.68	15.92	16.15	15.34
		2		15.289	15.82	
		3	15.72	15.69	15.44	
		4		15.2	14.99	15.37
		5		15.9	17.1	
Bayan-Ovoo	Male	1	14.5	14.7		
		2	15.2	15.72	16.34	15.8
		3		16.06	16.5	
		4		16.01	15.92	
		5	15.1	16.11	16.15	15.7
	Femal	1		14.84		
		2	14.98	14.49	16.4	
		3	15.45	15.75		
		4		15.69	15.8	
		5		16.63	17	
Norovlin	Male	1		15.74	15.2	
		2		15.33	15.38	
		3		15.43	15.1	
		4		15.64	15.55	
		5			16.08	
	Femal	1		15.34	16.3,	
		2	15.7	15.05	15.43	
		3			15.9	
		4		15.8	16.4	
		5		15.98	16.47	

Table 4

Calculation of the averages for the factors – soum, sex and age

Soum	Sex	Age					$\bar{x}_{ijk**}$
		1	2	3	4	5	
Galshir	Male	$\bar{x}_{111**} = 14.708$	$\bar{x}_{112**} = 16.048$	$\bar{x}_{113**} = 15.44$	$\bar{x}_{114**} = 15.61$	$\bar{x}_{115**} = 1574$	$\bar{x}_{11k**} = 15.509$
	Female	$\bar{x}_{121**} = 15.772$	$\bar{x}_{122**} = 15.56$	$\bar{x}_{123**} = 15.62$	$\bar{x}_{124**} = 15.18$	$\bar{x}_{125**} = 16.5$	$\bar{x}_{12k**} = 15.726$
		$\bar{x}_{1j1**} = 15.24$	$\bar{x}_{1j2**} = 15.804$	$\bar{x}_{1j3**} = 15.53$	$\bar{x}_{1j4**} = 15.395$	$\bar{x}_{1j5**} = 16.12$	$\bar{x}_{1jk**} = 15.617$
Bayan-Ovoo	Male	$\bar{x}_{211**} = 14.6$	$\bar{x}_{212**} = 15.765$	$\bar{x}_{213**} = 16.28$	$\bar{x}_{214**} = 15.965$	$\bar{x}_{215**} = 15.765$	$\bar{x}_{21k**} = 15.675$
	Female	$\bar{x}_{221**} = 14.84$	$\bar{x}_{222**} = 15.29$	$\bar{x}_{223**} = 15.6$	$\bar{x}_{224**} = 15.745$	$\bar{x}_{225**} = 16.815$	$\bar{x}_{22k**} = 15.658$
		$\bar{x}_{2j1**} = 14.72$	$\bar{x}_{2j2**} = 15.527$	$\bar{x}_{2j3**} = 15.94$	$\bar{x}_{2j4**} = 15.855$	$\bar{x}_{2j5**} = 16.29$	$\bar{x}_{2jk**} = 15.666$
Norovlin	Male	$\bar{x}_{311**} = 15.47$	$\bar{x}_{312**} = 15.355$	$\bar{x}_{313**} = 15.27$	$\bar{x}_{314**} = 15.595$	$\bar{x}_{315**} = 15805$	$\bar{x}_{31k**} = 15.499$
	Female	$\bar{x}_{321**} = 15.82$	$\bar{x}_{322**} = 15.224$	$\bar{x}_{323**} = 15.78$	$\bar{x}_{324**} = 16.1$	$\bar{x}_{325**} = 16.23$	$\bar{x}_{32k**} = 15.831$
		$\bar{x}_{3j1**} = 15.645$	$\bar{x}_{3j2**} = 15.289$	$\bar{x}_{3j3**} = 15.525$	$\bar{x}_{3j4**} = 15.847$	$\bar{x}_{3j5**} = 16.017$	$\bar{x}_{3jk**} = 15.665$
	$\bar{x}_{ijk**}$	$\bar{x}_{ij1**} = 15.083$	$\bar{x}_{ij2**} = 15.54$	$\bar{x}_{ij3**} = 15.665$	$\bar{x}_{ij4**} = 15.699$	$\bar{x}_{ij5**} = 16.142$	$\bar{x}_{ijk**} = 15.626$

Next calculation is the same as the above. Averages for the factors – soum, sex, fibre length are $\bar{x}_{ij*d*} = 15.6035$, for the factors – soum, age, fibre length are $\bar{x}_{i*kd*} = 15.6253$, for the factors –sex, age, fibre length are $\bar{x}_{*jkd*} = 15.564$.

Table 5

Calculation of the averages for the factors – soum and sex

Soum	Sex		$\bar{x}_{ij***}$
	Male	*Female*	
Galshir	$\bar{x}_{11***} = 15.509$	$\bar{x}_{12***} = 15.726$	$\bar{x}_{1j***} = 15.617$
Bayan-ovoo	$\bar{x}_{21***} = 15.675$	$\bar{x}_{22***} = 15.658$	$\bar{x}_{2j***} = 15.666$
Norovlin	$\bar{x}_{31***} = 15.498$	$\bar{x}_{32***} = 15.828$	$\bar{x}_{3j***} = 15.663$
$\bar{x}_{ij***}$	$\bar{x}_{i1***} = 15.561$	$\bar{x}_{i2***} = 15.737$	$\bar{x}_{ij***} = 15.649$

Averages for the factors – soum and age are $\bar{x}_{i*k**} = 15.648$, for the factors – soum and fibre length are $\bar{x}_{i**d*} = 15.553$, for the factors –sex and fibre length are $\bar{x}_{*j*d*} = 15.5279$, for the factors – sex and age are $\bar{x}_{*jk**} = 15.59$, for the factors – age and fibre length are $\bar{x}_{**kd*} = 15.56$.

Table 6

Calculation of the averages for the factor - soum

Soum	$\bar{x}_{i****}$
Galshir	$\bar{x}_{1****} = 15.4927$
Bayan-ovoo	$\bar{x}_{2****} = 15.684$
Norovlin	$\bar{x}_{3****} = 15.676$
$\bar{x}_{i****}$	$\bar{x}_{i****} = 15.6176$

Average for the factor –sex is $\bar{x}_{*j***} = 15.6492$, for the factor –age is $\bar{x}_{**k**} = 15.636$, for the factor – fibre length is $\bar{x}_{***d*} = 15.603$.

Calculation of the sum of quadrates and variances:

$Q_1 = 2.4323$, $Q_2 = 2.389$, $Q_3 = 28.6762$, $Q_4 = 13.1466$, $Q_6 = 98.9343$, $Q_5 = 31.815$

$$S_1^2 = \frac{2.4323}{12} = 0.203, \quad S_2^2 = \frac{2.3897}{24} = 0.1, \quad S_3^2 = \frac{28.6762}{6} = 4.87,$$

$$S_4^2 = \frac{13.1466}{8} = 1.64, \quad S_5^2 = \frac{31.815}{24} = 1.33, \quad S_6^2 = \frac{98.9343}{182} = 0.543, \quad S^2 = 0.5894$$

$$F_A = \frac{0.203}{0.543} = 0.374, \quad F_B = \frac{0.1}{0.543} = 0.184, \quad F_C = \frac{4.87}{0.543} = 8.969, \quad F_D = \frac{1.64}{0.543} = 3.02,$$

$$F_{ABCD} = \frac{1.33}{0.543} = 2.449$$

As per "Soum" factor, the following hypothesis is suggested:

$H_0: \mu_1 = \mu_2 = \mu_3$
$H_1: \mu_1 \neq \mu_2 \neq \mu_3$ *and*
As for F_A analyzer, when degrees of freedom were $k_1 = 12$, $k_2 = 182$, and credence level was $\alpha = 0.05$, then it results $F_{\alpha,A} = 1.75$, $F_A < F_{\alpha,A}$- *therfore the main H_0 hypothesis is supported. This shows that geographic location has no effect on fibre diameter.*

As per "Goat sex" factor, the following hypothesis is suggested:

$H_0: \mu_1 = \mu_2$
$H_1: \mu_1 \neq \mu_2$ *and*
As for F_B analyzer, when degrees of freedom were $k_1 = 24$, $k_2 = 182$, and credence level was $\alpha = 0.05$, then it results $F_{\alpha,A} = 1.52$, $F_B < F_{\alpha,B}$ therefore the hypothesis H_0 is supported. It shows *that goat sex has no effect on fibre diameter.*

As per "Goat age" factor, the following hypothesis is suggested:

$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$
$H_1: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq \mu_5$ *and*

As for F_C analyzer when degrees of freedom were $k_1 = 6$, $k_2 = 182$ and credence level was $\alpha = 0.05$ then it results $F_{\alpha,B} = 2.09$, $F_C > F_{\alpha,C}$ therefore *the hypothesis H_0 is denied. It shows that age of a goat has an effect on fibre diameter indicator.*

As per "Fibre length" factor, the following hypothesis is suggested:
H_0： $\mu_1 = \mu_2 = \mu_3 = \mu_4$
H_1： $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$ *and*
As for F_D analyzer when degrees of freedom were $k_1 = 8$, $k_2 = 182$ and credence level was $\alpha = 0.05$

then it results $F_{\alpha,C} = 1.94$, and $F_D > F_{\alpha,D}$ therefore the hypothesis H_0 *is denied. It shows that the factor "fibre length" has an effect on fibre diameter indicator.*

As for F_{ABCD} analyzer when degrees of freedom were $k_1 = 24$, $k_2 = 182$ and credence level was $\alpha = 0.05$ then it results $F_{\alpha,ABC} = 1.52$. Because of $F_{ABCD} > F_{\alpha,ABCD}$ it is concluded that the force of interaction of the factors also has an effect on fibre diameter indicator.

CONCLUTION

1. Fibre diameter of goats of Khentii aimag that went under the research fluctuated between 13.70-18.10 µm, average was 115.63±0.005µm; female goats` fibre diameter fluctuated between 13.7-18.10 µm and average was 15.66±0.13 µm; while male goats` fibre diameter fluctuated between 13.8-17.40 µm and average was 15.60±0.005 µm. Fibre diameter of Galshar soum was thinner that average indicator by 0.13µm, male goat`s was thinner by 0.28 µm; Bayan-Ovoo soum`s goats` fibre diameter was thicker than average by 0.1 µm, male goats` was thicker by 0.24 µm and female goats` was thinner by by 0.01mkm; Norovlin soum goats`s fibre diameter was 0.04, male goats` was thinner by 0.14 µm, and female goats` was thicker by 0.09 µm.

2. Fibre length of goats of Khentii aimag that went under the research fluctuated between 3.57-7.13 cm, average was 5.13±0.004cm; female goats` fibre length fluctuated between 3.73-7.00 cm and average was 5.01±0.005; while male goats`

fibre length fluctuated between 3.57-7.13cm and average was 5.23±0.004cm; fibre length of Galshar soum goats was longer than average indicator by 0.14cm, female goat`s was longer by 0.18cm and male goats` was longer by 0.1cm; Bayan-Ovoo soum`s goats` fibre length was shorter by 0.26cm, female goats` fibre length was shorter by 0.42cm and male goats` was shorter by 0.11 cm; Norovlin soum goats`s fibre length was longer by 0.11cm, female goats` fibre length was longer by 0.02cm and male goats` by 0.18 cm.

3. In terms of the percentage of effects of each factor: the factor "Soum"`s effect percentage was 2.5%, and the effect percentage of the factor "Goat sex" was 1.23%, factor "Goat age" was 59.1%, and factor "Fibre length" was 20.14%, and factor "inter-reaction of all factors"`s effect percentage was 16.33%. Among these factors the strongest effect factor was the goat`s age. The average effect factors were fibre length and the effect of inter-reactions.

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