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INVESTIGATIONS CONCERNING THE CORRELATIONS BETWEEN INTERMEDIATE METABOLISM AND PRODUCTION METABOLISM IN THE BOTOSANI KARAKUL SHEEP BREED

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The paper describes the interdependences between several intermediate metabolism parameters and production traits in sheep belonging to the Botosani Karakul breed expressed by three interaction levels: *simple linear correlation* (***r***), *partial correlation* (***Rp***) and *multiple linear correlation* (***Rm***). The metabolic profile of sheep envisages either singular action of each metabolic factor or its interference interaction with other metabolic factors or joint action of all metabolic factors, as well as the interaction way in metabolic networks for the production trait exteriorization in animals. The metabolic parameters taken into question for this study were represented by five internal constant of organic nature (glycemia, lipemia, cholesterolemia, proteinemia, haemoglobinemia), blood indices that are involved in a significant proportion in the production metabolism. The other series of variables for the correlational analysis was represented by the sheep productions (meat, wool, milk). Using the partial and simple linear correlations the paper highlights the impact of each metabolic factor, by simple action or interference reactivity, on each production traits. At the same time, on the basis of multiple linear correlation coefficients, this study estimated the participation share of the five blood organic substances to the expression of production metabolism by the *analysis of determinants* or the *factor analysis*. Quantifying the contribution of these internal factors on the production traits of this breed was made by calculating the *determining coefficient* (R_m^2 or $\boldsymbol{F_{total}}$). Defining the characteristics of the correlations between metabolic parameters and traits production as well as the quantification of the contribution of these internal factors in profiling the production metabolism of the Botosani Karakul breed are sustainable tools for the mathematical modelling concerning the conversion of circulating substances of internal medium (derived in their turn from the feed intake) into animal productions in full compliance with the imperatives of an efficient animal husbandry.

Key words: correlation, production trait, metabolism, factor contribution, sheep.

INTRODUCTION

The study of metabolic profile in sheep should not be an aim in itself, a purely theoretical concern, a strict issue of fundamental research. Thorough knowledge of the nature and essence of metabolic profile in the farm animals acquires a practical importance because the metabolism, through the essence and specific processes that compose it, is closely linked to the vital functions of animal organism – phenomena on which depend ultimately the animal productivity[1, 4, 7, 9, 19]. It must respond to some applicative issues required by animal husbandry: increasing the production potential, improving the reproduction physiology, acclimatization and adaptation of animals to various environmental conditions, adapting them to different nutrition, breeding and exploitation technologies and the maintenance of animals in a perfect healthy condition[4, 6, 7, 27]. Achieving these goals is possible only through a detailed knowledge of the metabolic processes that occur in the sheep body and on the basis of this knowledge the intermediate metabolism can be directed towards the objective pursued by man. The intensity degree of metabolic processes, as well as their specificity put their mark on the exteriorization of morphological, production and reproduction parameters of sheep, as well as on their health[10, 22, 26].

The development of biochemical investigation methods determined more strikingly the orientation of scientific research in countries with advanced animal husbandry towards deciphering the inward metabolic processes of farm animals[1, 8, 12, 13, 14, 17, 18, 20, 25], starting from the idea that the level at which the biochemical and biophysical reactions carried out as well as their specificity influence directly the capacity of production, reproduction and adaptation to the environment or the health status of domestic animals[11, 15, 21, 29].

The main production of Karakul sheep type is the lamb pelt characterized by the colour multitude of hair and by fascinating design conferred by association way of hair fibres in curls. The lamb pelts is a qualitative production trait[11, 28]. But, in addition to lamb pelt, the Karakul sheep, like all sheep breeds, also produces important quantities of meat, wool and milk[28]. The referred context imposed the metabolic testing of the Botosani Karakul sheep and determining the interdependencies between the quantitative production traits and the circulating organic substances in the blood of animal body in a perspective of assessing the influence of intermediate metabolism on the production metabolism.

MATERIALS AND METHODS

The metabolic profile test and evaluation of production traits were carried out on three sheep populations belonging to the Botosani Karakul breed from the *Research and Development Station for Sheep and Goat Breeding, Popauti-Botosani*, constituted in relation to age and gender of animals: 194 lambs (0-3 months), 169 adult females and 177 adult males.

The metabolic profile of these populations included five blood organic substances (glucose, lipids, cholesterol, protein and haemoglobin), considered to be the most important in the production metabolism. From the biochemical point of view, the five internal constants were spectro-photemetrically dosed:

– glycemia – by orto-toluidin method;
– lipemia – by P.S.V. (phosphorus-sulphur-vanillin) method;
– cholesterolemia – by Rappaport method;
– proteinemia – by Weichselbaum method;
– haemoglobinemia – by Drabkin method.

The quantitative traits of the Botoşani Karakul sheep, analyzed depending on age and gender, were determined by weighing and measurements, as follows:

- in lambs (0-3 months): body weight at birth; lamb pelt surface at birth; body weight at weaning; body weight gain at 90 days; daily average body weight gain. The body weight at weaning, body weight gain at 90 days and daily average body weight gain define the growth rate of animal body;
- in adult females: body weight; wool production; total milk production; milking period; daily average milk production.
- in adult males: body weight; wool production;

Both the metabolic parameters and the production traits represented the constituent elements of the correlation matrix. Depending on the correlation type, three coefficients were calculated: ***r*** for the simple linear correlation, ***Rp*** for the partial correlation and ***Rm*** for the multiple linear correlation[23]. The statistical relevance of these coefficients was assessed according to their critical values of the three significance levels: 0.05, 0.01 and 0.001. To estimate the participation rate of the organic blood substances to the exteriorization of production metabolism, the *determinining coefficient* was calculated quantifying the *contribution of factors* (R_m^2 or F_{total})[10, 23].

RESULTS AND DISCUSSION

CORRELATIONAL CHARACTERISTICS

Various metabolites resulted from the conversion of organic nourishments or from degradation of the animal body biostructures are produced in concentrations ranging within the limits of biochemical and physiological homeostasis of internal medium[4, 7, 9, 19, 27]. But these metabolites have not an isolated or unilateral action in the animal body; they perform reciprocal combinations, reacting more or less complexly, leading to specific manifestations of living matter, including to the exteriorization of production characters[11, 13, 14]. The influence that the metabolic parameters may have on the production traits can be quantified through a statistical indicator – *the correlation*[3, 5, 15, 23].

The correlation analysis aims to measure the interdependence degree between two or among more variables. The correlation can not prove a causal relationship, a link from cause to effect among the variables. But the interdependence can be functional and it can be expressed by a mathematical law, such as the linear relationship formula[2, 3, 5].

Whatever type interactions, the correlations are established between a *dependent variable* (Y), which is a certain trait of production, on the one hand, and one or more *independent variables* (*x*) representing one or more biochemical parameters, on the other hand. These connection types show how the dependent variable is modified to the fluctuations of independent variables[5, 23].

Depending on the number of independent random variables in the correlational system, the correlations are of three types according to the following mathematical expressions (models):

The **simple linear correlations** include both the influence of metabolic factor incriminated and the interference action of the other metabolic factors (which are present in system) on the production parameters, at which the experimental error is added.

$$\mathbf{Y \Leftrightarrow x_1 \leftarrow (x_2 x_3 x_4 .... x_n + e_{exp})}$$

The simple linear correlation coefficients (***r***) can take positive or negative values in the range –1 and +1. The simple linear correlations are the most commonly used analyzes in studies regarding the influence of metabolic parameters on the production characters.

In the **partial correlations** the influence which would have the interaction of the metabolic factor at issue with other metabolic parameters on the expression of the production potential is systematically eliminated; so, by this type of correlation only the singular (pure) action of a biochemical parameter on a certain production trait is aimed, other biochemical parameters being present in system, but they are considered to be constant, invariable and does not affect the correlation in question.

$$\mathbf{Y \Leftrightarrow x_1 * x_2 x_3 x_4 .... x_n}$$

The partial correlation coefficients (***Rp***) have weaker intensities than in the simple linear correlations and also can take positive or negative values ranging from –1 to 1. Of all types of correlations, the partial correlation is less commonly used in such studies. The partial correlations may have varying degrees of magnitude in a hierarchical relationship, depending on the number of metabolic factors that performs the simple action, this size order evolving from n-1 to 1. The partial correlation coefficient indicates the relative importance of each independent variable.

$$\mathbf{Y \Leftrightarrow x_1 x_2 * x_3 x_4 .... x_n}$$
$$\mathbf{Y \Leftrightarrow x_1 x_2 x_3 x_4 .... * x_n}$$

When the partial correlations reached the magnitude degree 0 (zero), these become multiple linear correlations. Because the cascading action of the independent variables some authors consider the partial correlation as a *partial multiple correlation*[3, 5].

Highly important for the expression of production potential is overall action of all circulating substances in the metabolic networks of the body. This interdependence is given by the **multiple linear correlation**.

The multiple linear correlation is the highest level of correlational systems performed between the intermediate metabolism and the production metabolism. Unlike the simple linear correlations and the partial ones, in the multiple linear correlations the interaction is established between the production trait, on the one hand, and all metabolic parameters taken as a whole, on the other hand.Therefore, the multiple linear correlation expresses the overall action of intermediate metabolism parameters on the various features of production metabolism. Therefore, even if they are not used on a larger scale, the multiple linear correlations give the best and safest information regarding the interdependencies between the biochemical indicators and production

$$\mathbf{Y \Leftrightarrow x_1 x_2 x_3 x_4 .... x_n}$$

traits of animals.

The multiple linear correlation can be calculated only on the basis of simple linear correlation coefficients of all variables involved. In contrast to the simple linear and partial correlations, the multiple linear correlation coefficients ($\boldsymbol{R_m}$) are always positive and take values from 0 to 1 (but not more than 1) and are higher than any simple correlation coefficient taken into the calculation algorithm. The influence of combined action of the independent variables has led some statisticians to consider the multiple linear correlation as a *total multiple correlation*[3, 5].

SIMPLE LINEAR CORRELATIONS

a) Simple linear correlations between organic internal constants and production traits in lambs (Table 1)

In lambs, except haemoglobinemia, the other internal constants are correlated very weakly with body weight at birth and lamb pelt surface. Perhaps at birth the metabolic profile of newborn lamb, still dependent on the intrauterine life conditions, is not well defined.

The closest interrelations are established between the haemoglobin and the other production parameters: body weight at weaning (very significant), body weight gain achieved at 90 days and daily average gain (distinct significant). This inherent link between haemoglobin and production traits expressing the lamb growth rate is due to the intense metabolism of young body which in this period requests an appreciable load with oxyhaemoglobinn of blood flow towards the growing tissues. An appreciable correlation, though it is not significant, is achieved by haemoglobin with body weight at birth and lamb pelt surface. Nevertheless this relation is not significant in statistical terms, probably the newborn lamb is dependent still of the maternal haemoglobin level through the blood flow established at placental level in the intrauterine period.

Table 1

Simple linear correlations between internal organic constants and production traits in lambs belonging to the Botosani Karakul breed

Correlation variables		**Correlation coefficients (r)**
Glycemia –	body weight at birth	0.002
	lamb pelt surface	0.002
	body weight at weaning	0.131^{+}
	body weight gain at 90 days	0.135^{+}
	daily average body weight gain	0.132^{+}
Lipemia –	body weight at birth	–0.040
	lamb pelt surface	–0.040
	body weight at weaning	0.044
	body weight gain at 90 days	0.042
	daily average body weight gain	0.051
Cholesterolemia –	body weight at birth	–0.001
	lamb pelt surface	–0.001
	body weight at weaning	0.034
	body weight gain at 90 days	0.031
	daily average body weight gain	0.031
Proteinemia –	body weight at birth	0.030
	lamb pelt surface	0.030
	body weight at weaning	0.133^{+}
	body weight gain at 90 days	0.131^{+}
	daily average body weight gain	0.127^{+}
Haemoglobinemia –	body weight at birth	0.118^{+}
	lamb pelt surface	0.118^{+}
	body weight at weaning	0.237^{***}
	body weight gain at 90 days	0.218^{**}
	daily average body weight gain	0.215^{**}
Liberty degrees		192
Significance thresholds	5%	0.141
	1%	0.185
	0.1%	0.235

Relatively intense correlations, whose values are placed next to the first critical threshold of significance (5%) are achieved by glycemia and proteinemia with the production parameters targeting the growth rate of lambs (body weight at weaning, body weight gain at 90 days and daily average gain). So the young body needs, besides a well oxygenated haemoglobin, also plastic material (protein) and energy (carbohydrates).

Lipemia and cholesterolemia are correlated weakly both with body weight at birth (even in a negative sense) and with the parameters that define the growth rate of lambs.

b) Simple linear correlations between organic internal constants and production traits in adult ewes
(Table 2)

In adult females, glycemia is correlated significantly with wool production; also it is correlated relatively well with body weight although the interaction does not present statistical assurance. The other correlation coefficients are low and unsignificant.

Table 2

Simple linear correlations between internal organic constants and production traits in adult ewes belonging to the Botosani Karakul breed

Correlation variables		**Correlation coefficients (r)**
Glycemia –	body weight	0.113^{+}
	wool production	0.128^{*}
	total milk production	0.010
	milking period	–0.072
	daily average milk production	0.045
Lipemia –	body weight	0.255^{***}
	wool production	0.182^{*}
	total milk production	0.036
	milking period	–0.011
	daily average milk production	0.034
Cholesterolemia –	body weight	–0.060
	wool production	0.077
	total milk production	0.063
	milking period	–0.025
	daily average milk production	0.072
Proteinemia –	body weight	0.064
	wool production	–0.041
	total milk production	–0.041
	milking period	–0.077
	daily average milk production	–0.028
Haemoglobinemia –	body weight	0.064
	wool production	0.056
	total milk production	-0.126^{-}
	milking period	-0.283^{000}
	daily average milk production	0.016
Liberty degrees		167
Significance thresholds	5 %	0.152
	1%	0.199
	0.1 %	0.250

Of all internal organic constants, serum lipids are the best correlated with production parameters: body weight (very significantly) and wool production (significantly); but the correlations with lactogenic parameters are very weak.

A very strong correlation (very significant), but of inverse type, is between haemoglobin and milking period. Also a negative but unsignificant correlation, which is close to the 5% threshold, is achieved between haemoglobin level and milk production. Haemoglobinemia is correlated very weakly with the other production characters (body weight and wool production).

The correlations established by the production traits of adult females, both with the cholesterolemia and with proteinemia, are extremely weak and unsignificant and in the most cases are negative.

The strong and significant corelations, both of blood glucose and serum lipids with meat and wool productions might be because some carbohydrates and fat in the macromolecular formulae that enter into the composition of muscle and fat tissues or constitute plastic material in the wool structure. In adult females an insignificant antagonism of proteinemia with wool production, milk production, milking period and daily average milk production is noted. This issue would be due to the protein “export” from blood serum towards production organs: hair follicles and mammary glandular acini, here taking place the conversion of serum protein in specific protein of sheep productions, keratin from wool, respectively, casein from milk. Also, the increase of milk production may lead, to some extent, to the decrease of haemoglobin concentration.

It should also be noted that all metabolic parameters are negatively correlated with lactation period. This phenomenon is an internal mechanism to protect the adult ewes against their exhaustion due to their prolonged exploitation by milking.

Therefore in the application of exploiting technologies in the Botosani Karakul adult ewes it must be taken into account, in a differentiated way, of the productions pursued. For meat and wool productions the feed rations should be rich in carbohydrates and fat and for the wool and milk productions these rations should contain protein substances as to avoid eventual metabolic deviations caused by hypoproteinemia. It should also be carefully established the milking duration because the prolonged exploitation of females by milking them could lead to their debilitation.

c) Simple linear correlations between organic internal constants and production traits in adult rams
(Table 3)

Unlike adult females, in adult males, almost all organic internal constants are better correlated with the two production parameters: body weight and wool production. Glycemia is well correlated both with body weight (significantly) and with wool production (distinctly significantly). Unlike ewes, in adult rams lipemia is more closely correlated with wool production (significantly) and very weakly with meat production. Instead, proteinemia is quite well correlated (significantly) with body weight, this correlation being very weak in adult ewes. Also in males there is a slight antagonism between proteinemia and wool production due to the same phenomenon of protein “export” towards hair follicles.

In rams, compared to ewes, haemoglobinemia is more closely correlated, almost significantly, with body weight. This could be due to the fact that body weight of adult males is bigger and more compact than of the adult females and for its irrigation a more intensive blood influx with a higher oxyhaemoglobin load is necessary. Maybe that is why maintaining a high concentration of haemoglobin in blood causes a slowed irrigation of hair follicles which would have the effect an insignificant decreasing of wool production or, alternatively, increasing the wool production would cause a slight decrease of circulating haemoglobin.

Table 3

Simple linear correlations between internal organic constants and production traits in adult rams belonging to the Botosani Karakul breed

Correlation variables		**Correlation coefficients (r)**
Glycemia –	body weight	0.149*
	wool production	0.202**
Lipemia –	body weight	0.035
	wool production	0.160*
Cholesterolemia –	body weight	–0.046
	wool production	0.081
Proteinemia –	body weight	0.179*
	wool production	–0.043
Hemoglobinemia –	body weight	0.122+
	wool production	–0.043
Liberty degrees		175
Significance thresholds	5%	0.148
	1%	0.194
	0.1 %	0.245

So, in adult rams, too, in application of exploitation technologies, it must be taken into account their metabolic needs in accordance with productions pursued. For meat production the feed rations should contain protein and carbohydrate substances; also the adult rams should benefit from technological conditions that provide a substantial irrigation with oxyhaemoglobin of the muscle tissues. For wool production the males require a substantial contribution of carbohydrate and fat, as well as of protein. Also it should pay attention to animal oxygenation when applying the intensive technologies to increase wool production to avoid their debilitation. Both in lambs and in adult animals, whether female or male, there is a low interaction of cholesterolemia with production traits, in some cases these interrelations showing even a slight antagonism. Perhaps the cholesterol has a more important role in the steroidogenesis process by its catabolising in pregnenolone, it being less involved in the production metabolism.

Correlational analysis in sheep of Botosani Karakul breed indicates that the sense, intensity and signification of interrelations between the circulating organic substances and production parameters are influenced by age and gender. The knowledge of these correlational aspects allows the proper resolving of nutrition, maintenance and breeding technologies of these animals according to the metabolic needs required by age and gender for the purpose of production potential exteriorization at the desired parameters by the livestock practice.

PARTIAL CORRELATIONS

a) Partial correlations between production traits and internal organic constants in lambs
(Table 4)

In the first tree months of life of Botosani Karakul lambs, the most considerable partial correlations are achieved by haemoglobinemia with the production parameters that define the growth rate of animal body (distinctly significant) and even with the body weight at lamb birth and with their body surface (close to the first critical significance limit). As well, the correlations of glycemia with the production traits concerning the lamb growth rate are close to the 5% significance threshold.

Table 4

Partial correlations between production traits and internal organic constants in lambs belonging to the Botosani Karakul breed

Correlation variables		Correlation coefficients **(Rp)**
Body weight at birth -	glyc. * lip. chol. prot. haem.	0.010
	lip. * glyc. chol. prot. haem.	–0.045
	chol. * glyc. lip. prot. haem.	–0.017
	prot. * glyc. lip. chol. haem.	0.015
	haem. * glyc. lip. chol. prot.	0.120+
Lamb pelt surface at birth -	glyc. * lip. chol. prot. haem.	0.010
	lip. * glyc. chol. prot. haem.	–0.045
	chol. * glyc. lip. prot. haem.	–0.017
	prot. * glyc. lip. chol. haem.	0.015
	haem. * glyc. lip. chol. prot.	0.120+
Body weight at weaning –	glyc. * lip. chol. prot. haem.	0.122+
	lip. * glyc. chol. prot. haem.	0.003
	chol. * glyc. lip. prot. haem.	–0.029
	prot. * glyc. lip. chol. haem.	0.090
	haem. * glyc. lip. chol. prot.	0.224**
Body weight gain after 90 days –	glyc. * lip. chol. prot. haem.	0.127+
	lip. * glyc. chol. prot. haem.	0.001
	chol. * glyc. lip. prot. haem.	–0.027
	prot. * glyc. lip. chol. haem.	0.090
	haem. * glyc. lip. chol. prot.	0.205**
Daily average body weight gain -	glyc. * lip. chol. prot. haem.	0.122+
	lip. * glyc. chol. prot. haem.	0.012
	chol. * glyc. lip. prot. haem.	–0.029
	prot. * glyc. lip. chol. haem.	0.086
	haem. * glyc. lip. chol. prot.	0.202**
Liberty degrees		188
Significance thresholds	5 %	0.143
	1 %	0.187
	0.1 %	0.237

glyc. – glycemia; **lip**. – lipemia; **chol.** – cholesterolemia; **prot.** – proteinemia; **haem**. – haemoglobinemia.

b) Partial correlations between production traits and internal organic constants in adult ewes
(Table 5)

In the adult females the most relevant partial correlations are achieved by lipemia with body weight (of direct type) and by haemoglobinemia with milking period (of rerverse type), both being very significant. The negative correlations between cholesterolemia and meat production, between haemoglobinemia and milk production, as well as the positive one between lipemia and wool production can be mentioned, all of them being close to the first significance threshold.

Table 5

Partial correlations between production traits and internal organic constants in adult females belonging to the Botosani Karakul breed

Correlation variables		Correlation coefficients **(Rp)**
Body weight –	glyc. * lip. chol. prot. haem.	0.029
	lip. * glyc. chol. prot. haem.	0.264^{***}
	chol. * glyc. lip. prot. haem.	$–0.138^{-}$
	prot. * glyc. lip. chol. haem.	0.101
	haem. * glyc. lip. chol. prot.	0.043
Wool production –	glyc. * lip. chol. prot. haem.	0.072
	lip. * glyc. chol. prot. haem.	0.134^{+}
	chol. * glyc. lip. prot. haem.	0.043
	prot. * glyc. lip. chol. haem.	–0.038
	haem. * glyc. lip. chol. prot.	0.049
Total milk production –	glyc. * lip. chol. prot. haem.	0.009
	lip. * glyc. chol. prot. haem.	0.019
	chol. * glyc. lip. prot. haem.	0.054
	prot. * glyc. lip. chol. haem.	–0.047
	haem. * glyc. lip. chol. prot.	$–0.123^{-}$
Milking period –	glyc. * lip. chol. prot. haem.	–0.050
	lip. * glyc. chol. prot. haem.	–0.017
	chol. * glyc. lip. prot. haem.	–0.032
	prot. * glyc. lip. chol. haem.	–0.063
	haem. * glyc. lip. chol. prot.	$–0.278^{000}$
Daily average milk production –	glyc. * lip. chol. prot. haem.	0.053
	lip. * glyc. chol. prot. haem.	0.001
	chol. * glyc. lip. prot. haem.	0.071
	prot. * glyc. lip. chol. haem.	–0.037
	haem. * glyc. lip. chol. prot.	–0.018
Liberty degrees		163
Significance thresholds	5 %	0.153
	1 %	0.201
	0.1 %	0.252

glyc. – glycemia; **lip**. – lipemia; **chol.** – cholesterolemia; **prot.** – proteinemia; **haem**. – haemoglobinemia.

c) Partial correlations between production traits and internal organic constants in adult rams (Table 6)

In the adult males the most eloquent partial correlations are of direct type being achieved by body weight with glycemia (significant) and with proteinemia (distinctly significant). Judging by their intensity, the partial interdependences of direct type between haemoglobinemia and body weight, but especially between glycemia and wool production are considerable too.

Table 6

Partial correlations between production traits and internal organic constants in adult males belonging to the Botosani Karakul breed

Correlation variables		Correlation coefficients **(Rp)**
Body weight –	glyc. * lip. chol. prot. haem.	0.184*
	lip. * glyc. chol. prot. haem.	–0.042
	chol. * glyc. lip. prot. haem.	–0.078
	prot. * glyc. lip. chol. haem.	0.205^{**}
	haem. * glyc. lip. chol. prot.	0.122^{+}
Wool production –	glyc. * lip. chol. prot. haem.	0.146^{+}
	lip. * glyc. chol. prot. haem.	0.092
	chol. * glyc. lip. prot. haem.	0.048
	prot. * glyc. lip. chol. haem.	–0.032
	haem. * glyc. lip. chol. prot.	–0.056
Liberty degrees		171
Significance thresholds	5 %	0.150
	1 %	0.197
	0.1 %	0.247

glyc. – glycemia; **lip**. – lipemia; **chol.** – cholesterolemia; **prot.** – proteinemia; **haem**. – haemoglobinemia.*

An overall ascertainment of these statistical processing reveal that in the Botosani Karakul sheep, regardless of age and gender of animals, the partial correlations of direct type between metabolic factors and production parameters have lower intensities in comparison with the linear simple correlations. Some positive simple linear correlations change their sense in the partial correlations, so that the last become of reverse type and thus the number of negative partial correlations increases. Also, already most negative interrelations develop a more pronounced antagonism between the metabolic parameters and the production traits by passing them from simple linear correlations to partial correlations. But the most relevant aspect is the decrease both of the number of significant partial correlations and of their significance degree, comparatively with the linear simple correlations. The changes of this correlational panel happen because of the unilateral action of each biochemical parameter by removing the interference reactivity of the other metabolic factors. Therefore, for the production metabolism exteriorization, various biochemical parameters do not act unilaterally, but they are in a constant competition and interraction in the metabolic networks of animal bodies. The interaction of the metabolic factors, hidden in the case of partial correlations, but manifest in the simple linear correlations, makes to increase the importance of each biochemical parameter, taken separately, in the metabolic economy of animal organism for the conversion of organic substances in specific animal productions.The partial correlation issue is much more intricate, it being able to approach the pure action not only of a single metabolic factor, but of two or more biochemical factors too, the other factors of the correlational system remaining constant until there are reached the linear multiple correlations which include the common action and influence of all metabolic parameters on the production features. Thus, there are achieved partial correlations of different size orders, but their study is extremely complex, difficult and laborious. The magnitude order of the partial correlations is calculated subtracting one unit out of the total number of independent variables. The variable extracted from system is considered the fluctuating variable and the others represent the independent variables. If the number of independent constant variables is more numerous the partial correlations has a higher size order. For example, in the expression below the partial correlation is of the second size order.

*Wool production – cholesterolemia glycemia lipemia *proteinemia haemoglobinemia*

The more the magnitude order is higher the more the partial correlation is easily calculated. If some of these independent constant variables become fluctuating and achieve the pure action of two or more metabolic factors, the partial correlation reduces in order of magnitude and its computation gets more complicated[23]. When all independent variable of system becomes fluctuating then the partial correlation is transformed into multiple linear correlation, situation materialized by equation:

Body weight at weaning – haemoglobinemia glycemia lipemia cholesterolemia proteinemia

In the present study the partial correlations are of the fourth order:

*Body weight – lipemia * glycemia cholesterolemia proteinemia haemoglobinemia*

This interpretation manner points out that the partial correlations represent the weakest interaction between two variables, constituting the first level of the correlational systems. Due to the approach complexity, the partial correlations occupy a very narrow area within the theoretical and applied research. However their utilisation would elucidate in a greater extend the informational status about the metabolic behaviour of each internal blood constant; thus, the contribution of each biochemical parameter at the exteriorization of the production traits could increases by the directing and improvement of the animal intermediate metabolism.

MULTIPLE LINEAR CORRELATIONS

In lambs, all the five internal organic constants correlates very significantly with those production parameters that define the growing rate (weaning body weight, gain achieved at 90 days and daily average gain); the multiple linear correlations resulted from the combined action of these internal blood constants and the production parameters of lambs at their birth (birth body weight and lamb pelt surface) have lower intensities, but by their coefficient values these correlations are very close to the first critical threshold of significance. This latter aspect could be due to the fact that the metabolism of newborn lamb is still dependent on the mother one; meanwhile, with the body growth, the individual acquires metabolic specificity which, in its turn, is reflected on the production traits of this sheep.

In adult females, all the five internal organic constants achieved very significant multiple linear correlations with body weight and milking period; their correlation with wool production is significant. The multiple linear correlations between the five blood indicators with total milk production and daily average milk production are unsignificant, but the values of their correlation coefficients are very close to the first critical threshold of significance.

In adult males, the combined action of the five biochemical parameters influences very significantly the body weight and distinctly significantly the wool production.

So, in general, regardless of age and gender, the overall interaction of intermediate metabolism parameters in their reciprocity are correlated with the production metabolism parameters in different degrees of significance.

*

A particularly important application of the multiple linear correlations is a statistical analysis named *the factor contribution* [10, 23]. The process for determining the factor contribution is also called the *analysis of determinants*. By the contribution of factors it is understood the participation share of variation of some random variables within the multidimensional system to achieve the variation of another random variable in the system. It is also called determinant analysis because the *determining coefficients* are used in this equation, they showing how much the variation of a variable is caused by the variation of another variable or of the other variables. The determining coefficient is obtained by squaring the multiple linear correlation coefficient.

In lambs the contribution of the five organic substances in the bloodstream to the achievement of body weight gain reflected in the growth rhythm of the young body is between 7% and 8% while for defining the two parameters from its birth this contribution is quite low (1%–2%).

In the adult ewe population the overall contribution of the five internal organic constants is more evident for exteriorization of body weight (9%–10%), more moderate for wool production (3%–4%) and less important for milk production (2%). It is worth mentioning that the contribution of the five circulating organic substances is considerably to prolong the ewe lactation (9%), even if they do not significantly influence the milk production.

As with the adult females, also **in adult ram** population, the five internal organic constants have a more significant contribution to the achievement of body weight (8%–9%) and a more moderate one on the expression of wool production (5%–6%).

Table 7

Multiple linear correlations between production traits and organic internal constants and factor contribution in sheep belonging to the Botosani Karakul breed, depending on age and gender

Animal populations	Correlation variables		Rm	R_m^2 (F_{total}) (%)
Lambs (0–3 months) N=194	Body weight at birth –	glyc. lip. chol. prot. haem.	0.130^{+}	1.69
	Lamb pelt surface –		0.130^{+}	1.69
	Body weight at weaning –		0.277^{***}	7.67
	Body weight gain after 90 days –		0.275^{***}	7.56
	Daily average gain –		0.278^{***}	7.73
	Liberty degrees		188	
	Signification thresholds	5 %	0.143	
		1 %	0.187	
		0.1%	0.237	
Adult ewes N = 169	Body weight –	glyc. lip. chol. prot. haem.	0.304^{***}	9.24
	Wool production –		0.199^{*}	3.96
	Total milk production –		0.141^{+}	1.99
	Milking period –		0.299^{***}	8.94
	Daily average milk production –		0.106^{+}	1.12
	Liberty degrees		163	
	Signification thresholds	5 %	0.153	
		1 %	0.201	
		0.1%	0.252	
Adult rams N = 177	Body weight –	glyc. lip. chol. prot. haem.	0.285^{***}	8.12
	Wool production –		0.234^{**}	5.48
	Liberty degrees		171	
	Signification thresholds	5 %	0.150	
		1 %	0.197	
		0.1%	0.247	

glyc. – glycemia; **lip**. – lipemia; **chol.** – cholesterolemia; **prot.** – proteinemia; **haem**. – haemoglobinemia.

Thus, one can see that in the Botosani Karakul breed, regardless of age and gender of sheep, the five constant internal organic in their joint action have an input important to achieve production of meat (lambs, adult females, adult males), their contribution is more limited to achieve the wool production (adult females and adult males) and for milk production this contribution is low (adult ewes).

It is obvious that to achieve the three production types, in addition to the five internal organic constants, a multitude of other internal factors also take part such as other organic substances, mineral elements, enzymes of the biocatalytic system, other metabolites resulting from catabolising of various substances and biostructures, as well as various external factors of surrounding environment or of technological systems. It seems that in adult ewes, a special contribution to the achievement of milk production is given by the endocrine system and in the newborn lambs the contribution of internal maternal medium is determinative for the exteriorization of body weight at birth and lamb pelt surface.

From this perspective, the results of this research will be quite promising for livestock practice offering to sheep farmers important instruments in the breeding and exploitation process of animals. The mathematical models elaborated will contribute to the detailed knowledge of phenomena regarding the conversion of circulating substances from internal medium of animal organism in specific animal productions, enabling the directing of intermediate metabolism processes by proper nutrition and care technologies for improving the production metabolism. The result of such approach will be the improvement of morphological profile and the increase of production potential of all sheep breeds[16, 24].

CONCLUSIONS

The interdependencies between the organic biochemical constants from sheep blood and quantitative production traits in the Botosani Karakul breed were described by means of the correlations expressed on three interaction levels: simple linear correlation, partial correlation and multiple linear correlation.

The intensity, sense and significance of these correlations are determined by the metabolic peculiarities of animals relating to their age and gender.

The partial correlation is the lowest level of the interactions between the biochemical parameters and the quantitative production features, while the multiple linear correlations represent the highest level of these interactions; the simple linear correlations occupies a middle position regarding the intensity and significance of the relationship between the intermediate metabolism and the production one.

In the event of simple linear correlations and partial correlations the most important interactions are achieved by haemoglobinemia, glycemia and proteinemia with production traits regarding the body growth rhythm in lambs, lipemia and glycemia with body weight and wool production in adult ewes, glycemia with body weight and wool production, lipemia with wool production and proteinemia and hemoglobinemia with body weight in adult rams.

In the multiple linear correlations the interactions between the metabolic joint activity of organic internal constants and the production traits is too tight and most of them have different significance levels.

The analysis of determinants shows that the total contribution of metabolic factors for the production metabolism exteriorization, irrespective of the age and gender of sheep, is more important concerning meat production, more moderate on the wool production and weaker on the milk production.

The analysis of the factor contribution may constitute a premise of phenomenological modelling for sheep breeding to increase their production potential taking into account the intermediate metabolism peculiarities.

The approach of the correlations at all interaction levels between the metabolic factors and production traits is very important in theoretical and applied research because their utilisation would elucidate in a greater extend the informational status about the metabolic behaviour of blood biochemical parameters in the metabolic networks regarding their isolated or conjugated action and how they contribute to the achievement of specific productions of sheep.

The knowledge of these correlational peculiarities facilitates the improvement activity to increase the quantitative production traits in sheep controlling the intermediate metabolism by adequate nutrition and maintenance technologies applied in breeding animals.

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