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„DOKTOR'S (PhD) THESES”

RESEARCH ON THE CORRELATION BETWEEN THE BREED, THE MINERAL ELEMENT SUPPLY AND THE QUALITY OF LEGHORN OF SHEEP

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-2002-

1. PRELIMINARY

One basic demand for the profitability of the sheep industry is the healthy stock. The foot diseases of the sheep are quite frequent and may cause severe losses in the stock. It is a well-known fact that among the farm animals it is the sheep that consume their nutrients "walking" for the most time of their lives as they are out in the pasture 6-9 months in a year. Experiments show that the Merino type of sheep which give 87 % of Hungary's sheep stock are more susceptible to foot diseases than any other genotypes. The lameness caused by foot diseases and, due to this, the decreasing consumption of feed impair the productivity and life performance of the sheep. Among the foot diseases foot rot is the most common one, this is the reason why in my paper I dealt in the first place with the factors causing this ailment. One determining factor in the development of the foot rot is the mechanical condition and resistance of the foot-horn. A better mechanical quality horn can resist the invasion of bacteria better. So the animals with such quality horn are less susceptible to foot rot. In my paper I was trying to find out which exogen and endogen factors influence the mechanical quality of the foot-horn of the sheep.

2. OBJECTIVES

- To collect information on the mineral contents of the sheep concerning certain macro and micro elements.
- To obtain answer to the question whether there is a difference between the mineral content of the horn of the healthy sheep and that of the sheep infected with foot rot.
- To get to know if the genotype might influence the mineral composition or the pace of growth of the horn.
- To determine the hardness and the shock resistance from the mechanical parameters of the horn so as to find connection between these parameters and the water content as well as the mineral content of the horn.
- To find out whether nutrition and age have any influence on the mineral composition of the foot-horn concerning certain elements.

3. MATTER AND METHOD

I carried out my examinations in the period of 1990-1999. The database comprises the results of 694 samples taken from 178 sheep.

3.1. Methods to determine the element content of the organs

I took liver and kidney samples from slaughtered animals and fleece, blood and horn samples from live and dead animals as well. The examinations for the element content of the samples were completed in the accredited Agro-chemistry Laboratory of the Agricultural Professional Service in Hódmezővásárhely. After the adequate preparation of the samples the quantity of P and Na was determined by a spectro-photometric system, while we used atomic absorption method for determining the a Ca, Mg, Zn, Cu, Mn, Fe and Se elements.

3.2. Measuring the growth of the horn wall

I cut the hair leaning over the edge of the leghorn on the outer part of the right front leg and the rear leg of the sheep. At 10 mm-s distance from the rim of the edge-horn I filed a 1 mm wide groove into the horn wall, 2 cm-s from the hill-wall part. I used a measuring rod for measuring. As the horn wall grows downwards from the edge, the groove is getting lower and lower, so the distance between the skin and the groove is constantly growing. During the experiment, in 40-70 days I measured the distance between the groove and the edge-horn. I subtracted 10 mm-s from that result, I divided the rest by the number of the days, then I multiplied by 30. In this way I got the value of the monthly average growth of the horn (mm/month).

3.3. Determination of the mechanical parameters of the foot-horn

The mechanical parameters of the horn were determined by the 'Fund for Modern Technology' at the former University of Agricultural Sciences, Gödöllő.

Determination of the hardness of the horn

The hardness of the horn was determined by the Hungarian standard of "The determination of the hardness of Plastics, Ball-pressing method MSZ ISO 2039-1:1992", on the basis of the Brinell hardness measuring process. To determine the hardness of the horn-wall we used a KM. 02. type device usually applied for measuring the hardness of plastics. The hardness was determined by the HB 5/156/60 Brinell hardness value (N/mm^2) with the following process: a 5 mm ∅ steel ball with 156 N (Newton) force and 60 sec time was pressed into the horn. From the pressing depth (h) and the diameter of the ball (D) the surface of the pressing globe. The harder the examined material, the greater the loading force (N/mm^2) to 1 mm^2 surface, so the pressing depth is less as well as the surface of the pressing globe (mm^2).

Calculation of the hardness value:

$$HB = \frac{F}{\pi \cdot D \cdot h}$$

HB -5/156/60 Brinell hardness value (N/mm^2)

F = loading force in N (15N)

D = the diameter of the ball (5 mm)

h = pressing depth in mm-s

$\pi = D \cdot h$ = surface of the pressing globe (mm^2)

Determination of the shock resistance of the horn:

The shock resistance, which is inversely proportional to fragility, gives information on the fragility of the horn. The sample is broken with the help of a pendulum striking apparatus, the performance of which is known. The shock resistance (J/cm^2) of the sample is calculated from the remaining performance of the hammer of the pendulum striking apparatus after breaking the sample. The shock resistance means the work (J) necessary for breaking the trial material reflected to its diameter (cm^2). We made the examinations with a Dynstat-apparatus which measures the value of the striking work (J).

Calculation of the shock resistance value:

$$a_n = \frac{A_n}{b \cdot h}$$

a_n = shock resistance (J/cm^2)

A_n = work necessary to break the sample (J)

b = width of sample (cm)

h = length of sample (cm)

3.4. Determination of the mineral composition of nutrients

- Determination of the Ca-content with the standard MSZ-08 1783/2-83,
- Determination of the Zn-content with the standard MSZ-08 1783/9-83,
- Determination of the Cu-content in compliance with the standard MSZ-08 1783/10-83, by the atomic absorption spectro-metric (AAS) method
- Determination of the P-content by the photometry method in compliance with the standard MSZ-08 1783/4-83.

The results were processed with the help of a computer. I estimated the differences between the average values of the groups by variance analysis. (F-probe, t-probe). The examinations of the connections were done with the help of a binary linear regression analysis.

4. THE RESULTS OF THE EXAMINATIONS, CONCLUSIONS

4.1. Mineral content in various breeds of healthy sheep

4.1.1. The mineral composition of the foot-horn of healthy Hungarian Merino, Awassi, British Milking and Fertile Merino sheep

In the case of each type, within each type, the hard horn wall contains more Ca than the soft bottom horn. These differences can be justified statistically.

In the case of each genotype, within each genotype, the Ca:P ratio of the hard horn wall is wider than that of the soft horn bottom, but the difference is only significant in the case of the Hungarian Merino (3.19; 2.01) in the level of $P <$ % . Among the examined types the foot horn of the British Milking sheep had the the widest Ca:P ratio (2.5), followed by the Fertile Merino (2.1), the Hungarian Merino (2.01) and finally the Awassi (1.6) (**Table 1.**). The results coincide with the statement of B. KOVÁCS (1977), that in the first place the hardness of the horn is given not by the absolute amount of the Ca and P, but by their ratio. LINDEMAN és MILLS (1980) found that the lack of Zn in sheep may cause feet deformities, as the creation of keratin is hindered. According to B. KOVÁCS (1977) a larger amount of Zn makes the horn harder while Cu makes it softer. My examinations support these findings, as the horn-wall of the Fertile Merino and

British Milking sheep with a harder, pigmented horn has a greater amount of Zn on the level of $P < 0,1$ % than the Hungarian Merino and Awassi (**Table 2.**).

The horn wall and the horn bottom of the "softer horned" Awassi on the level of $P < 0,1$ % contains more Cu than that of the other three types (**Table 2.**). According to B. KOVÁCS (1977), that the harder horn has a wider ratio of Ca:P than the softer ones, the order concerning the hardness of the horn is as follows:

- on the basis of the horn bottom: British Milking (3.23), Hungarian Merino (3,19), Fertile Merino (2.53), Awassi (2.33) (the differences are not significant)
- on the basis of the horn-wall: British Milking (2.5), Fertile Merino (2.1), Hungarian Merino (2.01), Awassi (1.6) (the differences between 1-3 and 2-4 on the level of $P <$ 5 % and between 1-4 on the level of $P < 1$ % are significant.)

1. táblázat

The Ca and P-contents of the foot-horn of Hungarian Merino. Awassi. British Milking and Fertile Merino (mg/kg)

Group	Type	n	Ca				P				Ca : P			
			Horn wall		Horn bottom		Horn wall		Horn bottom		Horn wall		Horn bottom	
			$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %
1.	Hungarian Merino (PM)	10	1810**	37.23	1152***	29.67	561	19.59	580	13.91	3.19**	27.74	2.01**	26.89
2.	Awassi (PM)	6	2182*	27.71	1211*	55.51	907	17.04	733	21.59	2.33	21.80	1.6	45.24
3.	British milk type (P)	16	2683***	30.45	1126***	20.03	848***	23.25	478***	33.25	3.23	30.58	2.5	23.78
4.	Fertile Merino (P)	10	3717***	38.24	888***	40.97	1478***	22.32	420***	18.86	2.53	32.01	2.1	32.61

P = pigmented horn; PM = unpigmented horn

Within type. between horn wall and bottom:
* P < 5 %   ** P < 1 %   *** P < 0.1 %

Between types. in Ca content of horn wall:
1.-4. P < 0.1 %   3.-4. P < 1 %
2.-4. P < 1 %   1.-3. P < 1 %

Between types. in P content of horn wall:
1.-4. P < 0.1 %   3.-4. P < 0.1 %   1.-3. P < 1 %
2.-4. P < 0.1 %   1.-2. P < 1 %

Between types. in P content of horn bottom:
1.-2. P < 1 %   1.-4. P < 1 %   2.-4. P < 0.1 %
1.-3. P < 5 %   2.-3. P < 0.1 %

Between types. in Ca content of horn bottom
no significant difference

Between types. in Ca : P ratio of horn bottom:
1.-3. P < 5 %
2.-4. P < 5 %
2.-3. P < 1 %

Table 2.

The Zn and Cu content of the foot-horn of Hungarian Merino. Awassi. British Milking and the Fertile Merino sheep (mg/kg)

Group	Type	n	Zn				Cu			
			horn wall		horn bottom		horn wall		horn bottom	
			$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %
1.	Magyar merinó (PM)	10	47.4	17.19	42.4	8.21	4.25	45.41	2.13	74.69
2.	Awassi (PM)	6	60.0	14.12	47.0	17.49	6.85	27.53	4.85	50.52
3.	Brit tejelő (P)	16	77.0*	19.77	41.0*	27.86	3.38	37.14	2.54	32.24
4.	Szapora merinó (P)	10	82.6*	11.17	34.0*	9.73	4.08*	25.93	1.16*	23.77

P = pigmentált szaru; PM = pigmentmentes szaru
* P < 0.1 %

Between types in Zn content of horn wall:
2.-3. P < 1 %   1.-4. P < 0.1 %
1.-3. P < 0.1 %   2.-4. P < 0.1 %

Between types in Zn content of horn bottom:
no significant difference

Between types. in Cu-content of horn wall:
1.-2. P < 0.1 %   2.-3. P < 0.1 %   2.-4. P < 0.1 %

Between types. in Cu-content of horn bottom:
1.-2. P < 0.1 %   2.-3. P < 1 %   2.-4. P < 0.1 %

4.1.2. The Ca:P ratio of the horn wall of healthy Hungarian Merino and Milking Cigája sheep

The Ca:P ratio of the pigmented horned Milking Cigája is almost the double (5.5) of the ratio of the unpigmented Merino (2.93) (P < 0,1 %)

4.1.3. The comparison of the Ca:P-ratios of the foot-horn of different genotype sheep on the basis of the results of examinations in different years (Table 3.)

Table 3.

The Ca:P ratio of the foot horn of different genotypes (partially different ages)

No.	Genotype	Horn	Ca:P ratio in horn wall			Ca:P ratio in horn bottom		
			n	$\bar{x}$	CV%	n	$\bar{x}$	CV%
1.	Hungarian Merino	PM	30	3.01	9.13	20	1.99	14.66
2.	Awassi	PM	10	2.19	36.60	10	1.67	15.98
3.	British Milking	P	10	3.36	9.22	10	2.57	16.92
4.	Corriedale	P	10	3.17	20.07	10	3.14	13.90
5.	Crossbred Eastern Fr.	P	8	3.45	23.51	8	2.74	30.80
6.	Milking Cigája	P	10	5.5	20.16	-	-	-

PM = unpigmented horn P = pigmented horn mm. = Hungarian Merino

Horn walll:
1.-2. P < 0.1 % 2.-3. P < 0.1 % 3.-6. P < 0.1 %
1.-5. P < 5 % 2.-4. P < 0.1 % 4.-6. P < 0.1 %
1.-6. P < 0.1 % 2.-6. P < 0.1 % 5.-6. P < 0.1 %
Horn bottom:
1.-2. P < 5 % 2.-3. P < 0.1 % 3.-4. P < 1 %
1.-3. P < 0.1 % 2.-4. P < 0.1 % 4.-5. P < 5 %
1.-4. P < 0.1 % 2.-5. P < 0.1 %
1.-5. P < 0.1 %

The order of the genotypes on the basis of the Ca:P ratio of the foot-horn:

Horn walll:

1. Milking Cigája (5.5), **2.** Crossbred Eastern Friesian (3.45), **3.** British Milking (3.36), **4.** Corriedale (3.17), **5.** Hungarian Merino (3.01), **6.** Awassi (2.19)

Horn bottom

1. Corriedale (3.14), **2.** Crossbred Eastern Friesian (2.74), **3.** British Milking (2.57), **4.** Hungarian Merino (1.99), **5.** Awassi (1.67) (The Milking Cigája had no results here).

The Ca:P ratio of the pigmented **horn wall** of the milk type Cigája on the level of $P < 0.1$ % is greater, that of the unpigmented Awassi is smaller than in the case of the other genotypes. There is no statistically verified difference between the pigmented-horned British Milking, Corriedale and the cross-bred genotype.

The Ca:P ratio of the pigmented **horn bottom** of the British Milking, Corriedale and the cross-bred genotype on the level of $P < 0,1$ % is greater than that of the unpigmented-horned Hungarian Merino and Awassi.
From the results I drew the conclusion that the pigmented-horned types, genotypes and animals are more resistant against foot diseases than the unpigmented ones as their horn, because of the wider Ca:P ratio, is harder. Sheep from wet climate areas (British Milking, Corriedale, Black Eastern Friesian, Cigája) need harder foot horn than sheep from dry areas (Merino, Awassi). This proves that the harder horn can compensate the softening effect of wet grounded pastures. The resistance against foot-diseases is influenced by the hardness of the horn bottom to a larger extent than that of the horn wall, because the horn bottom touches the ground on a larger surface, than the horn wall, which has a connection with the ground only by the carrier edge.

The grazing ability of the pigmented foot-horned genotypes with a larger Ca:P ratio (British Milking, Corriedale, cross-bred genotype, Milking Cigája) than that of the unpigmented-horned Awassi and Hungarian Merino. Awassi with the smallest Ca:P ratio has the weakest grazing ability of all examined genotype. Since agility and activity are parts of the grazing ability, the sheep need harder horn which can not soften easily in wet conditions, because it can resist foot diseases better than the soft horn. A part of the types with a higher genetic potential (British Milking, Black Eastern Friesian, Milking Cigája, Corriedale, suffolk, German black-headed meat-type sheep) used for the improvement of the fertility as well as the meat and milk productivity of the Hungarian Merino, have pigmented foot horn. It means that through cross-breeding these types with Merino leads, to some extent, not only to a better meat and milk productivity of the next generations, but also to a greater resistance against foot rot, than that of the pure-bred Hungarian Merino.

4.2. The effect of the age on the mineral composition of the foot horn

The Ca content (3096 mg/kg) of the foot horn of the Hungarian Merino ewes is larger and their Ca:P ratio (2.59) is wider than that of the young animals (2373 mg/kg) (1.83). These differences are significant on the P = 0,1 % level. It proves the practical experience that the horn of the older animals is harder and more resistant than that of the young animals. From the results I draw the conclusion that to bear the weight of the young animals with smaller weight a softer horn is adequate and enough. With the growing age of the animal grows the Ca content, the Ca:P ratio and consequently also the hardness of the horn. That is why the limb can fulfil its biological function, that is to carry the ever growing weight of the animal and to provide it the possibility to move.

On the basis of my previous examination the increase in the Ca:P ratio of the horn wall contributes 35 % to the decrease of the growth of the horn wall. The overgrown, and that is why deformed, soft foot horn could make the young animals excessively sensible to foot diseases. This is why, for overgrowth prevention, young sheep might need hoof-trimming more frequently than the adult aqnimals.

4.3. The mineral content of the organs and foot-horn of healthy Merino sheep and of those with foot diseases

4.3.1. The macro and micro element content of the organs of healthy Merino sheep and of those with foot diseases

The Ca content of the fleece of grazing sheep (1860 mg/kg) is larger than that of the indoor sheep (1760 mg/kg). The horn wall contains more Ca than the bottom of the horn in the case of both indoor groups while the bottom contains more Mg than the wall. The measured quantities prove the opinion of B. KOVÁCS (1977) stating that the Na concentration is larger in the wall of the horn than in the bottom of it, while in the case of the Mg it is vice versa. The Mn content of the fleece (2.8; 1.9 mg/kg) and the liver (2.4; 3.5 mg/kg) of the indoor sheep is rather little, and also the Zn content (fleece 48; 57 mg/kg) (liver 44; 35 mg/kg). It justifies the statement of REGIUSNÉ MŐCSÉNYI (1990) that it is only the pasture grass that can meet both the Mn (60 mg/kg) and Zn (40 mg/kg) requirement of the sheep, because the grass contains more Mn and Zn than the hay and the forage. The Mn content of the bottom of the horn of the grazing sheep (26 mg/kg) is the double the amount of that of the indoor animals (13.1; 15.1 mg/kg), the reason can be that with a better Mn supply the Mn content of the foot horn is also increasing.

4.3.2. The Ca, P, Zn and Cu contents of the foot horn of healthy Merino sheep and of those with foot diseases

The Ca content (1152 mg/kg) of the foot-horn of the healthy Merino group on the level of $P < 0,1$ % is greater than that of the sheep infected with foot rot (587 mg/kg). The horn of the ill sheep contained more P than that of the healthy sheep. Consequently the Ca:P-ratio (3.19:2.01) of the horn wall and the horn bottom on the level of $P < 1$ % is larger than that of the group infected with foot rot (2.35; 0.65). From these results we can draw a conclusion that in the case of the sheep infected with foot-rot the Ca content of the horn is decreasing.

According to SZOVÁTAY (2002) the reason for this can be that the blood supply in the foot is less since it is used less because of the pain, therefore less Ca can be built in the horn. This is why the Ca:P ratio is getting tighter and the hardness decreases as well.

On $P < 1$ % level I found negative linear correlation between the amount of Zn and Cu ($r = -0.77$), while at the healthy Awassi group at a $P < 5$ % level it is ($r = -0.86$). These coincide with the statement of ELINDER and PISCATOR (1977), according to which Zn and Cu are antagonistic.

4.4. The effect of the mineral element content of the foodstuff to the mineral content of the foot horn

- The Ca:P ratio of the foodstuff of Group 1. consuming pasture grass was 2.2 but the Ca:P ratio (1.3) of the foot horn is not larger – proven statistically – than that of Group 2. (1.2) consuming foodstuff with a poorer Ca content (1.69). It means that the foodstuff exceeding the necessary Ca:P ratio (1.6-1.7) only to a small extent (2.2) does not widen significantly the Ca:P ratio of the foot horn. Only in the case of giving significantly more Ca content fodder with a very wide Ca:P ratio is the Ca content (3465 mg/kg) of the foot horn significantly larger and the Ca:P ratio significantly wider.
- The Zn content (1.27 mg/kg) of 1 kg body weight of the sheep in Group 1. consuming pasture grass was only 7.6 % larger than that of Group 2. (1.18 mg/kg),

while the Zn content of the foot horn (90 mg/kg) was 23% (17 mg/kg) greater than that (73 mg/kg). A small rate Zn increase results in a growth in the Zn content of the horn, when the Zn content of the forage is around the minimal need.

4.5. The relation analysis of the mechanical parameters, water content and mineral composition of foot horn of sheep

4.5.1. The relation analysis of the hardness and mineral composition of foot horn

The relation analysis of the hardness and the Ca content of foot horn

The positive linear relation between the Ca content (X) and the Brinell hardness value (Y) of the air-dry horn containing 8 % water Y' = 21.663 + 0.0159 X (N/mm^2) is significant on the level of $P < 5$ %. A 1 mg/kg increase in the Ca content of the horn increases the Brinell hardness value of the horn by ≈ 0.02 N/mm^2. According to the determination coefficient (R2 = 0.3447) the increase in the Ca content of the horn contributes 34 % to the increase of the hardness of the horn (**Figure 1.)**

The relation analysis of the hardness and P content of the horn wall:

The negative linear relation between the P content (X) and the Brinell hardness value (Y) of the air-dry horn containing 8 % water Y' = 109.39 - 0.0391 X (N/mm^2) is significant on the level of $P < 5$ %. A 1 mg/kg increase in the P content of the horn decreases the Brinell hardness value of the horn by ≈ 0,04 N/mm^2.
According to the determination coefficient ($R^2 = 0.3172$) the increase in the P content of the horn contributes 32 % to the decrease of the hardness of the horn (**Figure 2.)**

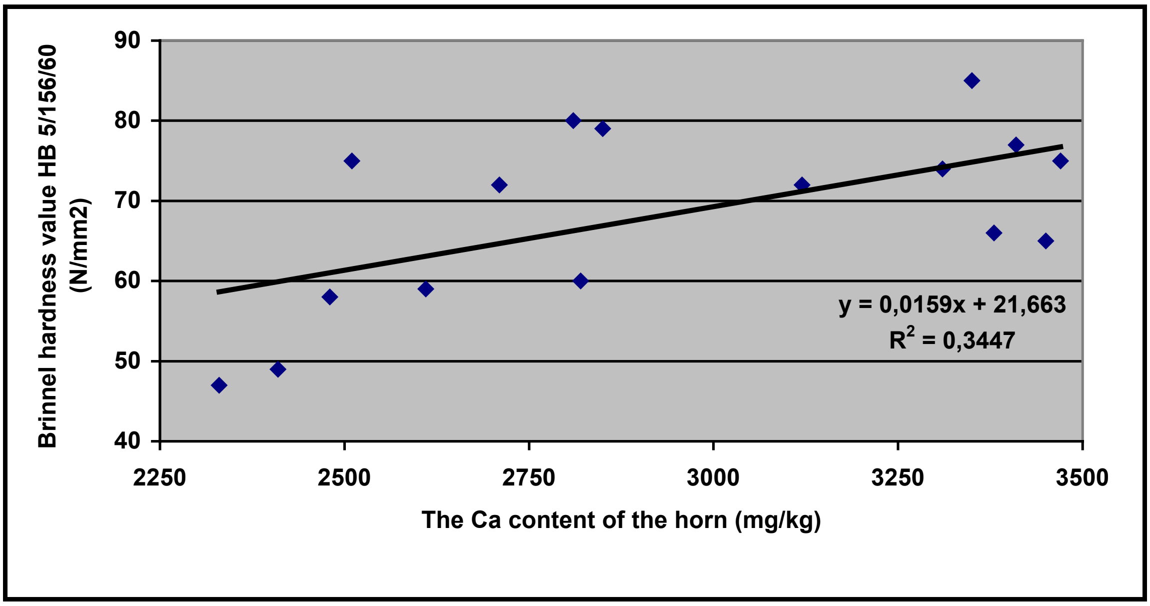
The relation analysis of the hardness and Ca:P ratio of the horn wall:

The positive linear relation between the Ca:P ratio (X) and the Brinell hardness value (Y) of the air-dry horn containing 8 % water Y' = 31.326 + 12.726 X (N/mm^2) is significant on the level of $P < 1$ %. When we increase the Ca:P value of the horn by 1 it increases the Brinell hardness value of the horn by 12.7 N/mm^2. According to the determination coefficient (R2 = 0.5008) the increase in the Ca:P ratio of the horn contributes 50 % to the increase of the hardness of the horn (**Figure 3.**).

Figure 4.

Figure 1.

Relation analysis of the hardness and Ca content of the horn wall
(air-dry horn with 8 % water content)
(binary linear regression analysis)

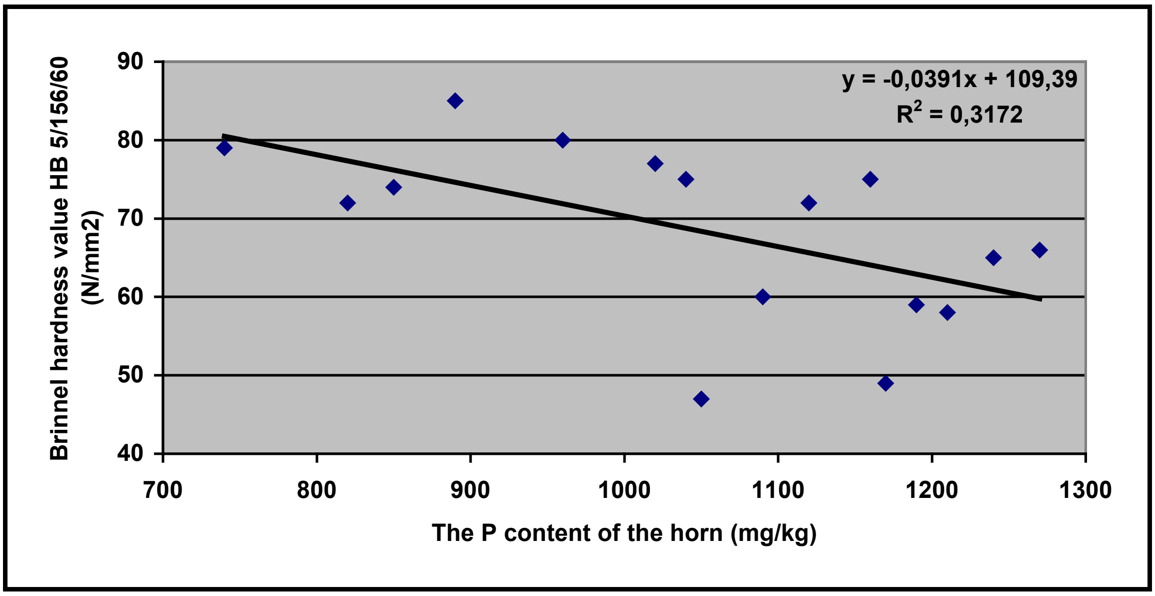


$Y' = 21.663 + 0.0159X (N/mm^2)$ **$F = 7.36$ ($F_{5\%} = 4.6$) $P < 5$**

$R^2 = 0.3447$ **$r = +0.59$ $n = 16$**

Figure 2.

Relation analysis of the hardness and P content of the horn wall
(air-dry horn with 8 % water content)
(binary linear regression analysis)

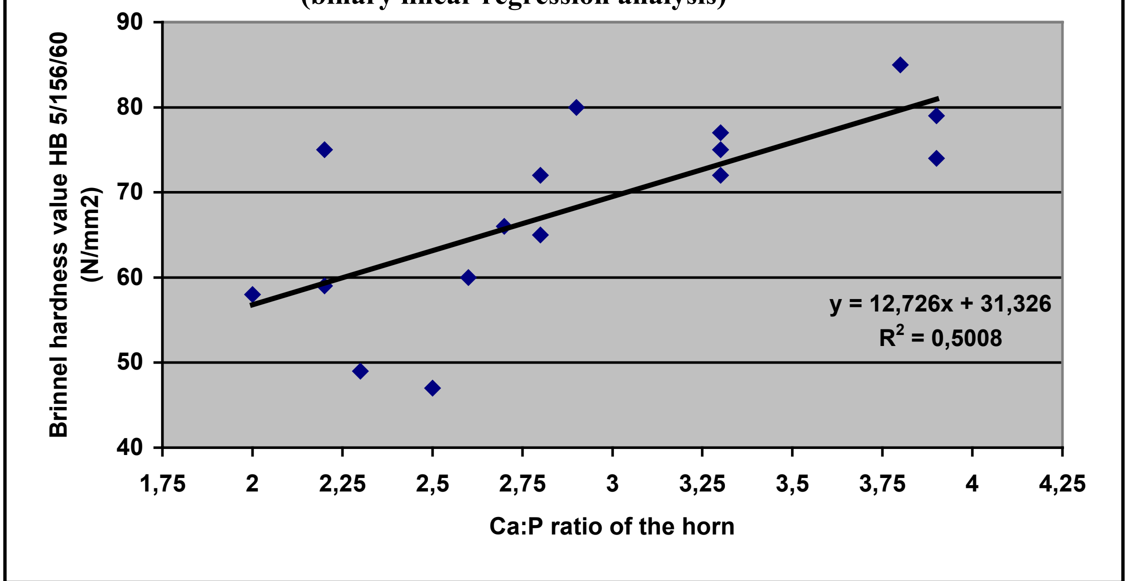


$Y' = 109.39 - 0.0391X (N/mm^2)$ $F = 6.5$ ($F_{5\%} = 4.6$) $P < 5$

$R^2 = 0.3172$ $r = -0.56$ $n = 16$

Figure 3.

Relation analysis of the hardness and Ca:P ratio of the horn
(air-dry horn with 8 % water content)
(binary linear regression analysis)

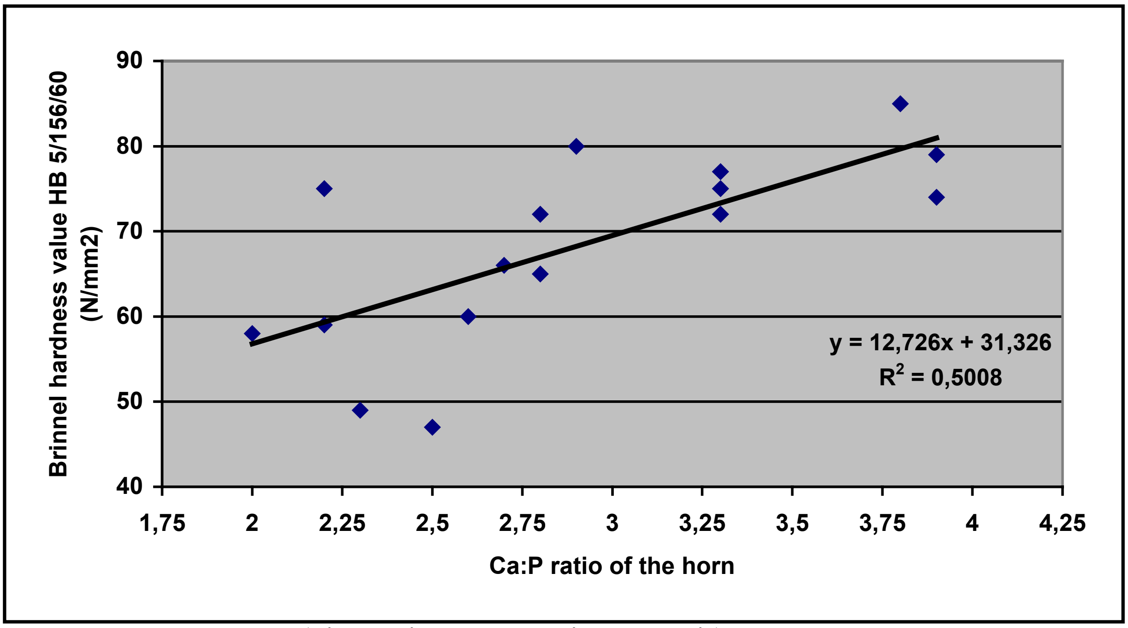


Y' = 31.326+12.726X(N/mm²) **F = 14.04 ($F_{1\%}$ = 8.86) P < 1**

R^2 = 0.5008 **r = +0.71** **n = 16**

Figure 4.

Relation analysis of the hardness and Zn content of the horn (air-dry horn with 8 % water content)



(binary linear regression analysis)

Y' = 30.016+0.5869X (N/mm²) **F = 4.66 ($F_{5\%}$ = 4.6) P < 5**

R^2 = 0.2499 **r = +0.5** **n = 16**

The relation analysis of the hardness and Zn content of the horn wall:

The positive linear relation between the Zn content (X) and the Brinell hardness value (Y) of the air-dry horn containing 8 % water Y' = 30.016 + 0.5869 X (N/mm²) is significant on the level of P < 5 %. A 1 mg/kg increase in the Zn content of the horn increases the Brinell hardness value of the horn by ≈ 0.6 N/mm².According to the determination coefficient (R^2 = 0.2499) the increase in the Zn content of the horn contributes 25 % to the increase of the hardness of the horn (**Figure 4.)**

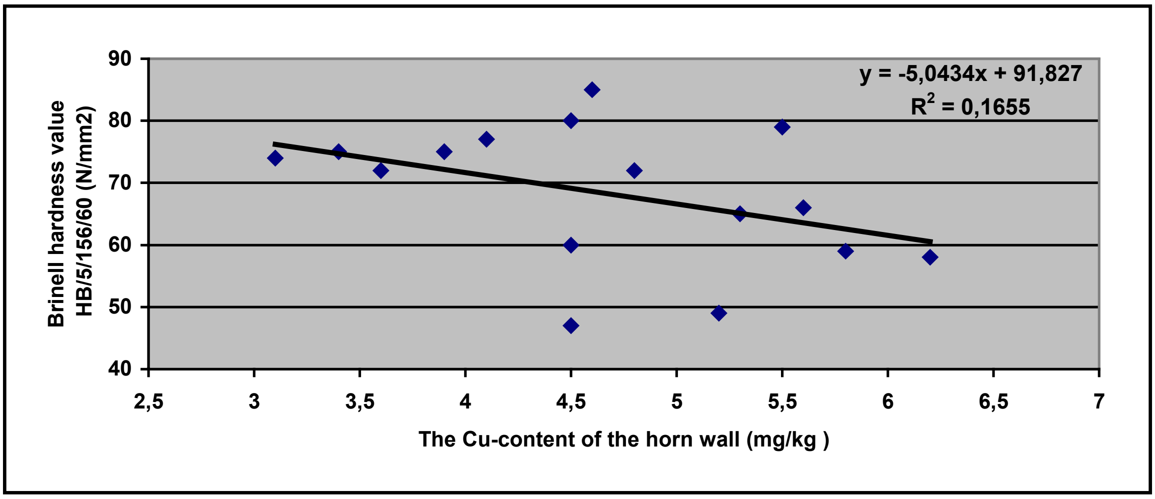
These results coincide with the opinion of LINDEMAN „et. al." (1980) and BIRES „et. al." (1990) that the higher Zn rate of the horn makes it harder, and the opinion of COENEN and SPITZLEI (1997), that with a smaller Zn content the hardness of the foot horn of horses decreases.

The relation analysis of the hardness and Cu content of the horn wall:

The negative linear relation between the Cu content (X) and the Brinell hardness value (Y) of the air-dry horn containing 8 % water Y' = 91.827 - 5.0434 X (N/mm^2) can not be proved statistically between the 3 and 6.5 Cu/kg values of the horn. (**Figure 5.**).

Figure 5.

Relation analysis of the hardness and Cu content of the horn
(air-dry horn with 8 % water content)
(binary linear regression analysis)



Y' = 91,827-5,0434X(N/mm^2)	**F = (2,78($F_{10\%}$ = 3,1) P > 10**
R^2 = 0,1655	**r = -0,4 n = 16**

This result, in this intervallum, does not reinforce the statement of B. KOVÁCS (1977) about cattle foot horn and the opinion of COENEN and SPITZLEI (1997) about horse foot horn, that a larger quantity of Cu makes the horn softer. According to SZOVÁTAY (2002) this may be connected to the fact that the Cu **sensitivity** of sheep differs from that of the cattle. **(Figure 5.)**

4.5.2. The relation analysis of the hardness and the water content of the horn wall:

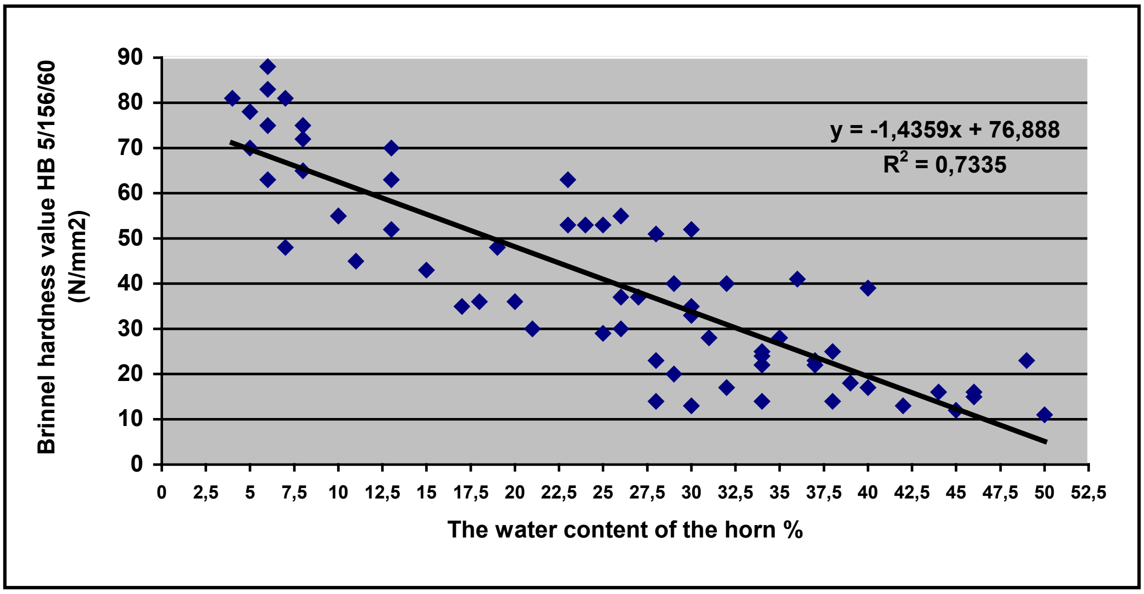
The negative linear relation between the water content (X) and the Brinell hardness values (Y) of the 4-50% water content horn Y' = 76.888 - 1.4359 X (J/mm^2) is (r = -0.86) is significant on the level of P < 0.1 %. The two variables are in close negative correlation with each other. A 1% increase in the water content of the horn decreases the Brinell hardness value by ≈ 1.4 N/mm^2. According to the determination coefficient the increase in the water content of the horn has ≈ 73 % (R^2 = 0.7335) influence on the decrease of the hardness of the horn. (**Figure 6.**)

The relation analysis of the <u>shock resistance</u> and <u>water content</u> of the horn wall:

The positive linear relation $Y' = 0.0254 + 0.0272\ X$ (J/cm^2) between the water content (X) and shock resistance (Y) of the horn is significant on the level of $P < 1$ % when the water content of the horn is 4-13 %. A 1 % increase in the water content of the horn increases the shock resistance by ≈ 0.037 J/cm^2. The two variables are in close correlation with each other ($r = +\ 079$). According to the determination coefficient ($R^2 = 0.6191$) the increase in the water content of the horn contributes 62 % to the growth of the shock resistance of the horn. It means that the horn with higher water content is softer and more flexible and it has a greater shock resistance than the horn with low water content, which is dryer and more fragile. The air-dry horn with 7-9 % water content provides the horn with the proper hardness and flexibility to complete its biological function. (**Figure 7.**)

Figure 6.

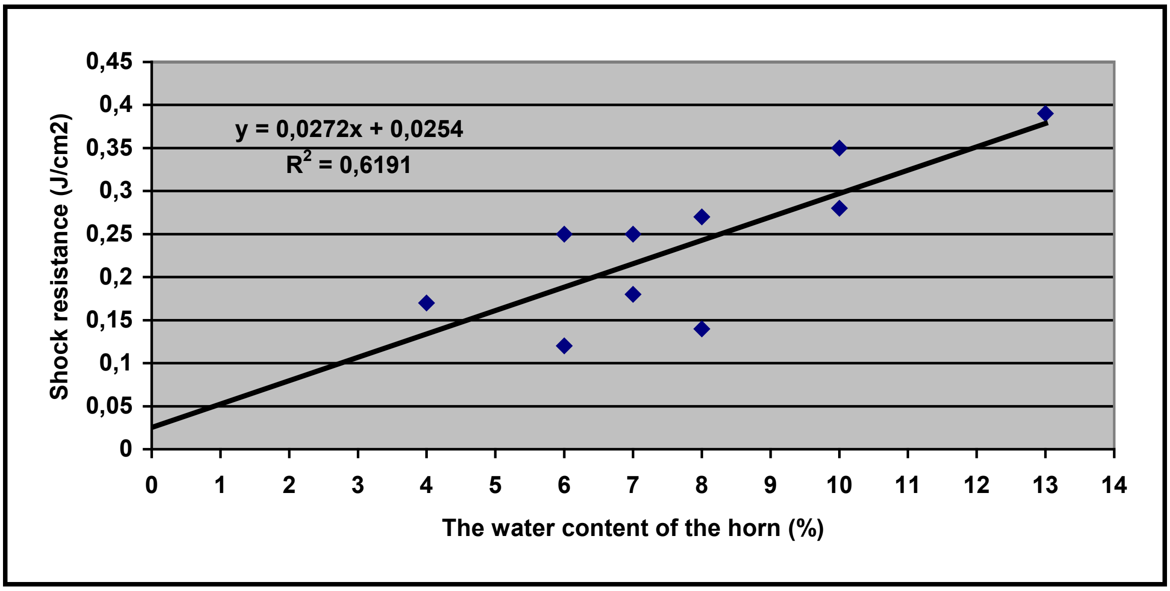
Relation analysis of the hardness and water content of the horn wall
(horn with 4-50 % water content)
(binary linear regression analysis)



Y' = 76.888 - 1.4359X(N/mm^2) **F = 170.63 ($F_{0,1\%}$ = 11.97)** **P < 0.1**
R^2=0.7335 **r = -0.86** **n = 6**

Figure 7.

Relation analysis of the water content and shock resistance of the horn wall
(horn with 4-50 % water content)
(binary linear regression analysis)



$Y' = 0.0254+0.0272X$ (J/cm^2) **$F = 13.00$ ($F_{1\%} = 11.26$) $P < 1$**

$R^2 = 0.6191$ **$r = +0.79$** **$n = 10$**

4.6. The effect of the mineral content on the growth of the foot horn in different breeds of sheep

4.6.1. The Ca:P ratio of the foot-horn of Awassi, Hungarian Merino and British Milking sheep

The Ca:P ratio of the harder horn wall of each genotype at the level of $P < 0,1$ % was significantly larger than that of the softer horn bottom. This proves the fact that the lower edge of the horn wall, the so called "carrier edge" has an important part in carrying the weight of the animal. This calls attention to the importance of the professional hoof trimming in due time. When the inside and outside part of the horn wall overgrows, leans onto the horn bottom and a so called "slipper hoof" will be formed. In this case increases the danger of the appearance of foot diseases but also the carrier edge will disappear and the hard horn wall is not able to function (carry the weight of the animal) properly. The Ca:P ratio of the horn bottom of the pigmented, more "steel-like-horned" British Milking sheep on the level of $P < 0,1$ % is larger than that of the Awassi and on the levels of $P < 1$ % and $P < 5$ %- it is larger than that of the two Merino groups (**Table 3.**). The results also support the opinion of **B. KOVÁCS** (1977) saying that the wider Ca:P-ratio of the horn increases its hardness.

The growth of the softer horn of the Awassi and Merino breeds, in most cases on the level of $P < 0,1$ %, $P < 1$ % and $P < 5$ %, is **significantly greater than that of the British Milking**. This is why it is ususally necessary to make hoof trimming more often than in the case of the pigmented horned British Milking. **(Table 5.)**

4.6.2. The Ca, P, Cu, Zn és Se contents of healthy Corriedale and Black Eastern Friesian x (Hungarian Merino x pleveni F_1) genotype sheep

In the case of these genotypes with harder horn wall the Ca:P ratio (3.17; 3.45) is not wider statistically than that of the horn bottom (3.14; 2.74) (**Table 6.).** This status is beneficial to prevent the development of foot rot.

The slower growth of the horn wall of the **Corriedale** is more favourable compared to the crossbred Eastern Fresian, as the overgrowth of the horn wall is likely to occur later, and therefore it **is necessary to make hoof-trimming more rarely** in the grazing period. (**Figure 7.**)

Table 4.

The Ca:P-ratio of the foot-horn of Awassi, Hungarian Merino and British Milking sheep

Groups		Foot horn	n	The mineral content of foot horn			
				Ca	P	Ca:P	
				mg/kg			
No.	Name			$\bar{x}$	$\bar{x}$	$\bar{x}$	CV %
1.	Awassi	F	10	2640	1210	2.19*	36.6
2.	Awassi	T	10	1701	1010	1.67*	15.9
3.	Magyar Merino (Törtel)	F	10	3410	1080	3.10*	10.4
4.	Magyar mernó (Törtel)	T	10	2304	1181	1.94*	34.3
5.	Magyar Merino (Túrkeve)	F	10	3138	1042	3.01*	6.2
6.	Magyar Merino (Túrkeve)	T	10	2210	1101	2.01*	9.2
7.	British Milking	F	10	3683	1098	3.36*	9.3
8.	British Milking	T	10	2468	958	2.57*	16.9

F = horn wall T = horn bottom

* Significant difference between horn wall and horn bottom on the level of P = 0.1 % within the type.

Difference between the Ca:P-ratios of foot horn in the different types:

horn wall: 1.-3. P < 1 % horn bottom: 6.-8. P < 5 %
1.-5. P < 1 % 4.-8. P < 1 %
1.-7. P < 0.1 % 2.-8. P < 0.1 %

Table 5.

The growing speed of the foot horn (wall) of Awassi, Hungaraian Merino and British Milking breeds

Groups		Limb	n	The growth of the foot horn (mm/month)		
No.	Name			$\bar{x}$	s	CV%
1.	Awassi	E	10	8,6	1,08	12,52
2.	Awassi	H	10	7,9	1,26	15,83
3.	Hungarian Merino (Törtel)	E	10	6,7*	0,47	7,01
4.	Hungarian Merino (Törtel)	H	10	5,7*	0,60	10,49
5.	Hungarian Merino (Túrkeve)	E	10	6,8*	0,81	11,94
6.	Hungarian Merino (Túrkeve)	H	10	5,8*	0,38	6,57
7.	British Milking	E	10	5,8*	0,55	9,44
8.	British Milking	H	10	4,8*	0,59	12,17

E - Front H - Rear

*** P < 1 % within breeds between the growth of the front and rear limb**

Within breeds (front limb):
1.-3. P < 0,1 %
1.-5. P < 0,1 %
1.-7. P < 0,1 %
3.-7. P < 1 %
5.-7. P < 1 %

Within breeds (rear limb):
2.-4. P < 0,1 %
2.-6. P < 0,1 %
2.-8. P < 0,1 %
4.-8. P < 5 %
6.-8. P < 1 %

Table 6.

The Caa, P, Cu, Zn and Se content and the Ca:P ratio of the Corriedale and Black Eastern Friesian x (Hungarian Merino x pleveni F1) (mg/kg)

No.	Group	n	Foot horn										
			Part of horn	Ca	P	Ca:P		Cu		Zn		Se	
				$\bar{x}$	$\bar{x}$	$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %	$\bar{x}$	CV %
1.	Corriedale	10	F	4779	1513	3.17	20.7	4.7	11.3	62.1	10.1	0.44	11.9
2.	Corriedale	10	T	3579	1130	3.14	13.9	4.4	19.3	40.6	13.0	0.30	34.9
3.	Black Eastern fr. x (mm.x pleveniF_1)	8	F	2875	890	3.45	23.5	4.0	19.0	56.8	20.4	0.34	20.1
4.	Black Eastern fr. x (mm.x pleveniF_1)	8	T	2908	1164	2.74	30.8	4.5	27.0	56.0	22.0	0.37	25.0

F = horn wall T = horn bottom mm. = Hungarian Merino

Zn content of foot horn:
1.-2. P < 0.1 %
2.-4. P < 1 %

Se content of foot horn:
1.-2. P < 1 %
1.-3. P < 5 %

Table 7.

The growing speed of the foot horn (wall) of Corriedale and crossbred Eastern Fresian sheep

Groups		Limb	n	Growth of foot horn (mm/month)		
No.	Name			$\bar{x}$	s	CV%
1.	Corriedale	E	10	6,6	1,3	19,63
2.	Corriedale	H	10	5,8	1,2	21,29
3.	Crossbred Eastern Fresian	E	8	8,2	2,4	29,67
4.	Crossbred Eastern Fresian	H	8	6,2	1,1	17,49

E - Front H - Rear mm. - Hungarian Merino

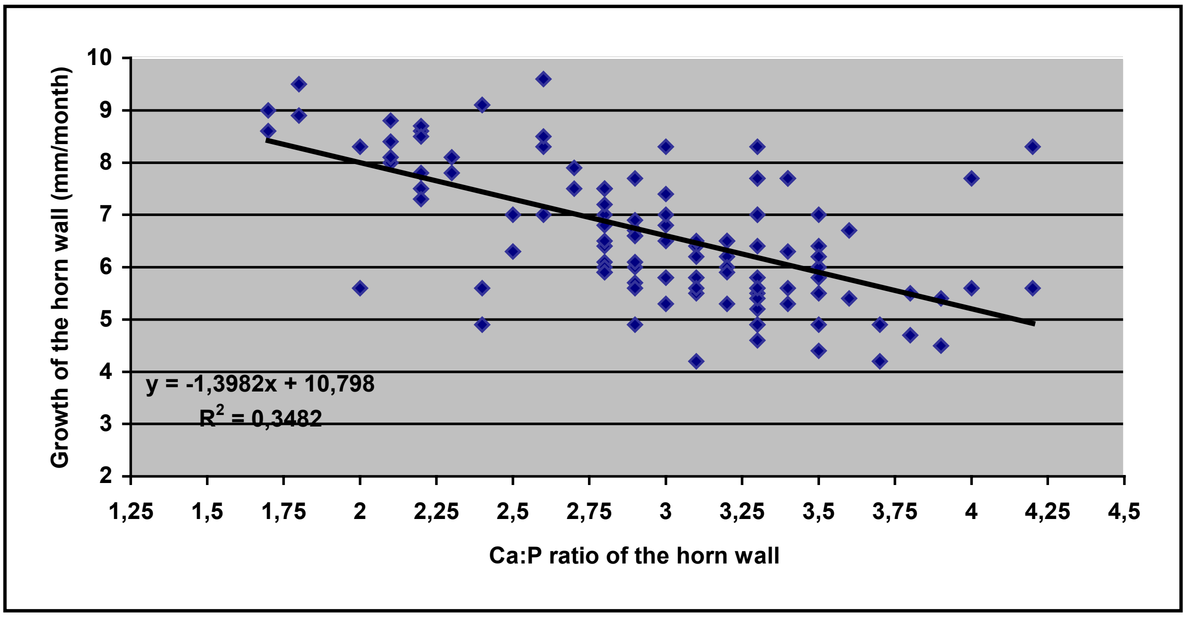
1.-3. P < 5 % 3.-4. P < 5 %

4.6.3. The relation analysis of Ca:P ratio and growth in the horn wall of sheep on the basis of research in different years (Figure 8.)

Between the Ca:P ratio of the horn wall (X) and its growth (Y) there is a negative linear relation Y' = 10.798 - 1.3892 X (mm^2/month), which is significant on the level of P < 0.1 %. Increasing the Ca:P value of the horn wall by 1 decreases the growth of the horn wall by 1.4 mm monthly. The negative relation between the two variables is middling (r = - 0.59). According to the determination coefficient the increase of the Ca:P ratio of the horn wall has a 35 % influence on the decrease in the growth of the horn wall (R^2 = 0.3482). The horn of the harder, pigmented-horned genotypes with a wider Ca:P ratio grow more slowly than that of the softer horned ones. That is the reason why hoof trimming to prevent the horn overgrowing and so to prevent foot diseases can be done less frequently with some the above mentioned types, occassionally.

Figure 8.

The relation analysis of Ca:P ratio and growth in the foot horn (horn wall)
(Bineary linear regression analysis)



Y' = 10.798 - 1.3982X (mm/month)   F = 60.91 ($F_{0,1\%}$ = 11.39) P < 0.1
R^2 = 0.3482   r = -0.59   n = 116

5. NEW AND NOVEL SCIENTIFIC RESULTS

5.1. The **Ca:P ratio of the horn wall** ($P < 0.1\%$,) of healthy sheep is wider and it is harder, than the horn bottom. The **pigmented foot horn** is harder than the unpigmented one, its **Ca:P ratio is wider** ($P < 0.1\%$, $P < 1\%$, $P < 5\%$), and it contains more Zn ($P < 0.1\%$, $P < 1\%$).

5.2. The **Ca content** of the healthy Hungarian Merino ewes is 50% greater ($P < 0.1\%$) and the **Ca:P ratio** of its horn wall and foot horn is **wider** ($P < 1\%$) than that of the young animals, and so it is harder.

5.3. The **Ca content** of the healthy Hungarian Merino ewes is 50% greater ($P < 0.1\%$) and the **Ca:P ratio** of its horn wall and foot horn is **wider** ($P < 1\%$) than that of the animals infected with some foot disease.

5.4. When feeding the sheep with fodder containing **large amount of Ca supplement** the Ca content of the foot horn increases ($P < 0.1\%$) and **its Ca:P ratio widens** ($P < 0.1\%$), therefore its hardness can also increase.

5.5.1. There is a positive linear relation $Y' = 31.326 + 12.726\ X$ (N/mm^2) between the **Ca:P ratio** (X) and the **Brinell hardness value** (Y) of the foot horn which is significant on the $P < 1\%$ level. A 1 increase in the Ca:P ratio increases the hardness of the horn 12.7 N/mm^2 . Increasing the Ca:P ratio of the horn by 1 means a 50 % contribution to the increase of the hardness ($R^2 = 0.5008$)of the horn.

5.5.2. The negative linear relation $Y' = 76.888 - 1.4359\ X$ (N/mm^2) between **the water content** (X) and the **Brinell hardness value** (Y) which is significant on the level of $P < 0.1\%$. A 1 % increase in the water content of the horn decreases the Brinell hardness value by 1.4 N/mm^2. The increase of the water content in the horn contributes 73 % to the decrease of the hardness of the horn.($R^2 = 0.7335$).

5.5.3. The positive linear relation $Y' = 0.0254 + 0.0272\ X$ (J/cm^2) between the **water content** (X) and the **shock resistance** (Y) of the horn is significant on the level of $P < 1\%$ when the water content is 4-13 %. A 1 % increase in the water content of the horn increases the shock resistance ($R^2 = 0.61911$).by 0.03 J/cm^2. The increase in the water content of the horn contributes 62 % to the increase of the shock resistance of the horn .

5.6. Between the **Ca:P ratio** of the wall of the foot horn (X) and its **growth** (Y) there is a negative linear relation Y'=10.798-1.3982 X (mm/month) which is significant on the $P < 0.1$ % level. When we increase the Ca:P ratio of the horn wall by 1 it decreases the growth of the horn wall by 1.4 mm every month. The increase of the Ca:P ratio of the horn wall contributes 35 % to the decrease ($R^2 = 0.3482$) of its growth

6. PRACTICAL UTILISATION OF THE RESULTS

6.1. When judging the looks and appearance of the Hungarian Merino the pigmented-horned animals should be favoured and not handicapped compared to the unpigmented animals, provided it does not deteriorate the fleece, milk and meat production ability. The greater hardness of the pigmented horn means greater resistence to foot-diseases.

6.2. I find it necessary to check the foot horn of the young indoor animals more frequently. Since the foot horn of young animals less hard, it can overgrow faster, and when taking them to a hard-soil area outside the building, the overgrown parts might be overloaded.

6.3. I recommend the pigmented-horned intensive milk and mutton sheep genotypes (British Milking, Milking Cigája, Black Eastern Friesian, Corriedale, German Back Head) as cross-breeding partners for the Hungarian Merino to create breeding animals and to improve their milk and meat production. Not only the genetic potential of the cross-bred breeding animals will increase, into the given direction of utilisation, compared to the pure-bred Merino sheep but also their ability to resist foot rot. This is due to the fact that their horn will be more pigmented than that of the pure-bred Merinos.

6.4. I would not recommend to try and increase the Ca content, Ca:P ratio and so the hardness of the horn by providing foodstuff with an excessive amount of Ca and with a wide Ca:P ratio that exceed the need of the animals. According to DITTRICH (1969/70) the wide Ca:P ratio hinders the uptake of micro elements from the alimentary tract and their utilisation within the body and the large amount of Ca decreases the uptake of nutrients, the utilisation of N and gaining weight.

6.5. The increase of the water content of the horn contributes 73 % to the decrease of the hardness of the horn. In order to prevent food diseases it is particularly important to keep the sheep away from low, wet pastures and not to let them out to graze before the morning dew has been dried up. On such grazing fields – beside the danger of endoparasitic infections – the thick and hard foot horn softens because of the wet conditions and it promotes the development of foot diseases. This is true both for pigmented and unpigmented foot horn types, since in softening the horn the water content has a greater role than the mineral content.

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