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EFFECT OF FEEDING ON SALT TOLERANT PLANTS ON PHYSICAL AND CHEMICAL PROPERTIES OF COAT FIBERS IN SHEEP

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ABSTRACT

The present study used the experimental work of technical cooperation project entitled "salt-tolerant forage production systems to salt-affected lands in Sinai Peninsula in Egypt" which supported by ICBA (International Center for Biosaline Agriculture). The aim of the present study was effect of feeding on salt tolerant plants ((*Kochia indica* and *Pennisetum americanum*) on physical and chemical properties of coat fibers in sheep. Twenty four male growing Barki lambs Twenty-four male growing (averaged six months of age and 18.8±0.89 Kg of body weight) were divided randomly into three groups given CFM (concentrate feed mixture) to cover 100% of maintenance requirement. Berseem hay (*Trifolium alexandrinum*) fed to the first group (G1) as a control diet. The total amount of (*Kochia indica*) and (*Pennisetum americanum*) grass mixture was divided into two equal parts: the first part was kept as hay to be fed for the second group (G2) while the other part was mixed with 5% molasses to make haylage for the third group (G3). Wool samples were taken to estimate fiber length (FL), fiber cross sectional area (FCSA), crimp frequency (CF), cotting score (CS), also amino acids; Threonine (Thr), Valine (Val), Methionine (Met), Isoleucine (Iso), Leucine (Leu), Phenylalanine (Phe), Histidine (His), Lysine (Lys), Aspartic acid (Asp), Serine (Ser), Glutamic acid (Glu), Proline (Pro), Glycine (Gly), Alanine (Ala), Cystine (Cys), Tyrosine (Tyr) and Arginine (Arg) were analyzed. Results showed a slight increase in all fiber amino acids contents for both G2 and G3 as compared with control. Results recorded marked differences in Cys, Ala, Asp, Arg, Thr and Met between all groups. Amino acids; Cys, Ala, Glu, Pro and Met showed a significant increase in G3 whereas only Met achieved a marked increase in the two treatment groups than control. Amino acid Met significantly increased in coarse and fine fibers of both G2 and G3, while Ala tended to be higher in only fine fibers of G3 as compared with control. There was no significant effect of treatment on the studied wool characteristics, except CS which significantly increased in G2 and G3. Within groups, FL slightly increased in coarse and fine fibers in both G2 and G3. The increase in FL of coarse fibers was significantly higher than fine fibers in G2 and G3. The same trend was observed in CS. The FCSA decreased in both coarse and fine fibers of G2 and G3 than control, this decline was higher in G3 than G2. Feeding on haylage might cause an increase in fiber length and fiber fineness through decreasing FCSA, and an increase of CF in fine fibers of G3 than G2 and a partially decline in CS. It could concluded that feeding on salt tolerant plants (*Kochia indica* and *Pennisetum americanum*) mixed with molasses may cause an increase in fiber amino acids contents which in turn make changes in physical characteristics of wool fibers viz.; an increase in fiber length and cotting score, and a decrease in fiber cross sectional area and crimp frequency of Barki lambs.

Keywords: Salt tolerant plants, amino acids, wool characteristics

INTRODUCTION

Wool and hair fibers are the end-product of complex processes that originate at the base of the animal skin. The wool and hair keratin molecule consists of a highly complex sequence of amino acids; Cystine, Lycine, Arginine, Glutamic acid and Aspartic acid important in the physiochemical properties of the fibers (Lewis, 1986). As the wool keratin synthesis requires essential amino-acids and especially sulphured amino-acids, it is necessary to meet with accuracy the nutritional requirements in order to produce high quality wool with a high yield for covering the demand (Lisovac and Shooter; 2003 and Purvis and Franklin; 2005). Wool contains higher concentrations of Serine and Arginine, as well as Cysteine. Serine and Arginine are both classified as non-essential amino acids. The response in wool growth to Serine and Arginine, either alone or in combinations with Methionine or Cysteine requires evaluation. The delivery of 0.7g of Methionine into the intestine of sheep resulted in increases in wool growth of 40% on native pasture and 18% on improved pasture (Langlands, 1970). While Methionine (as a precursor for Cysteine production) is accepted as the primary limiting amino acid under most conditions, additional increases of 38% in wool growth may be obtained if other limiting amino acids are supplied (Reis *et al*., 1990).

The salt tolerant plants (*Kochia indica* and *Pennisetum americanum*) are the future development for the salty lands especially with harsh conditions and become essential solution during drought season however, it could be used more efficiently as hay or silages rather than in fresh state because of these processing would improve their palatability and nutritive values (Youssef, *et al*., 2009). Generally, the rations must be formulated to support the optimum productivity, must be efficient and economical to feed, and must minimize the nutritional related problems (Al-Khalasi *et al*., 2010). In the same context, all nutrient digestibility coefficients particularly dry matter (DM), crude protein (CP), crude fiber (CF) and nitrogen free extract (NFE) were higher significantly in *Kochia Indica* compared to Berseem hay. Methionine has been shown to cause rapid increases in fiber growth (Sahoo and Soren, 2011). Provision of protected methionine to adult withers fed to maintenance increased the efficiency of conversion of metabolisable protein to wool from 12.3% to 17.2%, and increased wool production from 9.6 to 13.5 g/d (Mata *et al*., 1995). On the other hand, Imik and Gunlu (2011) have found that the elasticity, length and diameter of wool fibers have not significantly differed with sorghum uptake.

In the present study, it is noteworthy that identification and quantitative determinations were recorded for major amino acids in wool fibers. In addition, we have investigated the changes in these amino acids under feeding of some salt tolerant plants and determined the effect of these changes on the physical characteristics of coat wool fibers.

MATERIALS AND METHODS

The trial was done at South Sinai Research Station belongs to Desert Research Center, Egypt. Twenty-four male growing Barki lambs averaged six months of age and 18.8±0.89 Kg of body weight were used in the trial. The animals were divided randomly into three groups (8 animals/each) and concentrate feed mixture (CFM) was given to all animals to cover 100% of maintenance requirement (Kearl, 1982). The CFM consisted of 25% cotton seed cake, 30% corn, 35% wheat bran, 3% rice bran, 3% molasses, 1% urea, 2% limestone, 1% common salt. Large quantity of chopped air-dried of Kochia (*Kochia indica*) and Pearl millet grass (*Pennisetum americanum*) mixed together at a ratio of 47: 53%, respectively (Youssef, *et al*., 2009). The total amount of mixture was divided into two equal parts: the first part was kept as hay to be fed for the second group (G2) while the other part was mixed with 5% molasses to make haylage for the third group (G3). Both of these salt tolerant mixtures (STM) were given to sheep as basal diets in comparison with the berseem hay (*Trifolium alexandrinum*, 4th cut) fed to the first group (G1) as a control diet. These two salt tolerant plants; Kochia and Pearl millet grass were cultivated in salt affected soils of the research farm and irrigated with underground saline water (averaged 6000 ppm total dissolved salts), they were harvested around 17 and 13 ton/acre, respectively. The crude protein (CP) of used rations in the present study was 15.6 (CFM), 14.9, 9.30 and 11.0% for G1, G2 and G3, respectively according to Youssef *et al*. (2009). The experiment continued for 12 weeks. Twenty-four wool samples were taken from the left mid – side/animal of about 200-300 gm for each. Samples were divided into coarse fibers (medullated fibers) and fine fibers (non-medullated fibers). Fiber length (FL), fiber cross sectional area (FCSA), crimp frequency (CF) and cotting score (CS) were measured for all samples. Average lengths of hundred fibers taken randomly from each greasy sample were estimated by using a ruler to the nearest 0.5 cm for fiber length measurement. The fiber length was measured for the distance between the top and the end of the fiber with stretching. Fiber cross sectional area was calculated by the following equation according to (Dun, 1958);

$$\text{FCSA } (\mu m^2) = (0.5 * \text{fiber diameter})^2 \times 3.14$$

The number of crimps along each un-stretched fiber was counted and the average fiber length was calculated and used to obtain the number of crimps per one centimeter. Subjective graduation measurement was used to record cotting score in different grades (i.e. low, medium, high) for each sample. Cotting trait of wool means the matting of the different fibers together in the fleece (undesirable recipe in the industry). According to Moore and Stein (1958), an Amino Acid Analyzer was used to estimate wool fiber amino acids content. Wool representative samples of about 20 gm/each were hydrolyzed. Threonine (Thr), Valine (Val), Methionine (Met), Isoleucine (Iso), Leucine (Leu), Phenylalanine (Phe), Histidine (His), Lysine (Lys), Aspartic acid (Asp), Serine (Ser), Glutamic acid (Glu), Proline (Pro), Glycine (Gly), Alanine (Ala), Cystine (Cys), Tyrosine (Tyr) and Arginine (Arg) have been analyzed. The present study used the same experimental work of technical cooperation project entitled "salt-tolerant forage production systems to salt-affected lands in Sinai Peninsula in Egypt" which supported by ICBA (International Center for Biosaline Agriculture).

Data were statistically analyzed using one way analysis of variance with General Linear model (GLM) of SAS (2000) and differences between means were tested using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Salt tolerant plants and fiber amino acids contentes:

In spite of fiber types and treatment, data in (Table, 1) showed that amino acids; Glu and Pro were present in considerable relatively higher amounts than others, while Met was the lowest amount in all fibers (13.7, 13.5 and 0.88 residue/100, respectively) and the rest of amino acids were present in moderate amounts. Soussil *et al*. (2001) found that at low and medium salinity (as in some salt tolerant plants), Glu and Pro levels rose. Several investigations have shown that the level of free amino acids, especially Proline, increases during adaptation to various environmental stresses (Livia *et al*., 2002). Generally, in the present study the treatment caused a slight increase in all fiber amino acids contents for both G2 and G3 as compared with control. The *Kochia indica* and *Pennisetum americanum* could be considered to be moderately salt tolerant plants, showing stable symbiotic properties under saline conditions and the moderate levels of salt in the diet increased the proportion of protein escaping rumen degradation and the absorption of essential amino acids (Soussil *et al*. 1998). The overall mean of fiber amino acids composition illustrated that there were marked differences in Cys, Ala, Asp, Arg, Thr and Met between all groups, specially Met which significantly increased in G3 (1.05) than G2 (0.85) and G1 (0.73) residue/100, respectively. This result could refer to the treatment rations that could increase feed intake causing an increase in amino acids content particularly in G3 that fed haylage. Hamdia and Shaddad (2010) showed that the salt tolerant plants accumulated significantly higher organic osmotic (total free amino acids, soluble proteins and soluble sugars) under saline conditions. In addition, Francoise *et al*. (1991) found that salt stress induced a large increase in the amino acids and carbohydrate pools. In addition, Yap and Lim (1983) illustrated that salt significantly increased the total amino acids contents in all body cells.

It has been suggested that increases in total amino acids may be a consequence of protein degradation. The profile of studied amino acids by Kumar *et al*. (1999) showed major alterations at salinity levels suggesting that these changes may constitute adaptive responses to salt, allowing generally normal growth.

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Table (2) summarized the changes in amino acids composition of both coarse and fine fibers in all experimental groups. Amino acids; Cys, Ala, Glu, Pro and Met showed a significant increase in G3 whereas only Met achieved a marked increase in the two treatment groups than control. The amino acid Met significantly increased in coarse and fine fibers of both G2 and G3 while Ala tended to be higher in only fine fibers of G3 as compared with control. This result concluded that haylage could increase palatability causing an increment in feed intake and in turn, increasing in amino acids. It is well known that Methionine amino acid increased the efficiency of conversion of metabolisable protein to wool and in turn increased wool production (Mata *et al*. 1995). However, Ward (1998) found that wool contains higher concentrations of serine and Arginine, as well as Cysteine. Serine and Arginine, either alone or in combinations with Methionine or Cysteine increases wool growth. Francoise *et al*. (1991) stated that within the amino acids, Proline showed the largest increase. Its accumulation reflected an osmoregulatory mechanism in follicles tissue.

Table (2): Changes (+/-) in amino acids content of coarse and fine wool fibers in the two treated experimental groups than control group

Amino Acids	G2				G3			
	Coarse (+/-)		Fine (+/-)		Coarse (+/-)		Fine (+/-)	
Cys	+0.36	NS	+0.15	NS	+0.74	NS	**+0.72**	**S**
Ala	+0.65	NS	+0.63	NS	**+0.82**	**S**	**+0.81**	**S**
Ser	+0.15	NS	+0.43	NS	+0.24	NS	+0.59	NS
Glu	+0.57	NS	+0.21	NS	+1.02	NS	**+2.04**	**S**
Asp	+0.5	NS	+0.63	NS	+1.31	NS	+1.02	NS
Arg	+0.34	NS	+0.67	NS	+1.23	NS	+1.34	NS
Lys	+0.35	NS	+0.04	NS	+0.44	NS	+0.15	NS
Leu	+0.07	NS	+0.09	NS	+0.13	NS	+0.18	NS
Iso	+0.05	NS	+0.27	NS	+0.12	NS	+0.36	NS
Thr	+0.45	NS	+0.41	NS	+0.7	NS	+0.93	NS
His	+0.06	NS	+0.08	NS	+0.1	NS	+0.17	NS
Pro	+1.16	NS	+1.40	NS	**+1.53**	**S**	+1.65	NS
Tyr	+0.08	NS	+0.09	NS	+0.09	NS	+0.2	NS
Gly	+0.03	NS	+0.1	NS	+0.04	NS	+0.17	NS
Met	**+0.16**	**S**	**+0.07**	**S**	**+0.44**	**S**	**+0.2**	**S**
Val	+0.03	NS	+0.01	NS	+0.11	NS	+0.03	NS
Phe	+0.05	NS	+0.12	NS	+0.08	NS	+0.27	NS

G2: Hay feeding group, G3: Haylage feeding group. S: significant, NS: non-significant

Salt tolerant plants and fiber characteristics:

The studied wool fiber physical characteristics of the all experimental groups are presented in Table (3) and Figs.; 1, 2, 3 and 4. Between groups, there was no significant effect of treatment on the wool traits, except CS which significantly increased in G2 (0.51) and G3 (0.43) as compared with control (0.27). However, the increase in FL and decreases in FCSA and CF were not significant. Within groups, FL slightly increased in coarse and fine fibers in both G2 and G3 as compared with control, although these values did not reach to the significant level. However, the increase in FL in terms of coarse fibers was higher than in fine fibers of the two treated groups, this difference was significant (p>0.05). The same trend was observed in CS which significantly increased (p>0.05) in fine fibers than in coarse fibers of both G2 and G3, but fine fibers of G2 had higher increment of CS (0.57) than coarse fibers (0.44). From the same Table, FCSA decreased in both coarse and fine fibers of G2 and G3 than control, however, this decline was highly significant in G3 (742.77 and 185.57 in coarse and fine fibers, respectively) than G2. These differences between coarse and fine fibers were significant (p>0.05). The CF showed an opposite trend which G2 recorded lower values; 0.57 and 2.43/cm in coarse and fine fibers, respectively as compared with G3. These differences between coarse and fine fibers were also significant (p>0.05). This difference between coarse and fine fibers referred to the sizeable degree of heterogeneity in the chemical structure of the two types of wool. This heterogeneity are considered a keratinized tissue, containing several types of cells and these cells in turn, contain many protein constituents based on different content of amino acids (Ibrahim *et al*., 1978).These findings also concluded that the feeding on haylage might cause an increase of wool production in terms of increasing FL and fiber fineness through decreasing FCSA, in addition to cause relatively slightly increase of CF in fine fibers of G3 (2.55) than G2 (2.43) and also caused a partially decline in CS. Bas *et al*. (1994) stated that there is a high correlation between crimp value and wool fineness, and negative correlation between cross sectional area and fiber fineness.

Table (3): Physical characteristics of coarse and fine wool fibers (x±SE) **for the different experimental groups**

Traits	G1			G2			G3		
	Coarse	**Fine**	**Overall mean**	**Coarse**	**Fine**	**Overall mean**	**Coarse**	**Fine**	**Overall mean**
FL cm	7.13 ±0.84[a]	6.77 ±0.84[a]	6.95 ±0.59[A]	7.32 ±0.84[a]	7.15 ±0.84[a]	7.24 ±0.59[A]	7.88 ±0.84[a]	7.34 ±0.84[a]	7.61 ±0.59[A]
FCSA μm^2	919.24 ±69.15[a]	229.81 ±69.15[b]	574.53 ±48.90[A]	793.32 ±69.15[a]	198.33 ±69.15[b]	495.83 ±48.90[A]	742.27 ±69.15[a]	185.57 ±69.15[b]	463.92 ±48.90[A]
CF n/cm	0.89 ±0.22[b]	2.76 ±0.22[a]	1.83 ±0.16[A]	0.57 ±0.22[b]	2.43 ±0.22[a]	1.50 ±0.16[A]	0.69 ±0.22[b]	2.55 ±0.22[a]	1.62 ±0.16[A]
CS grades	0.20 ±0.05[d]	0.33 ±0.05[cd]	0.27 ±0.03[B]	0.44 ±0.05[bc]	0.57 ±0.05[ab]	0.51 ±0.03[A]	0.35 ±0.05[c]	0.51 ±0.05[ab]	0.43 ±0.03[A]

G1: Control group, G2: Hay feeding group, G3: Haylage feeding group. Capital super script means differences between overall means. Small super script means differences between fine and coarse fibers.

Kulkarni (1980) and Azzam *et al*. (2002) reported that fine wool had a higher sulphur amino acid content Cys than that of the coarse fibers. Azzam *et al*. (2002) found that the fine fibers had higher contents of amino acids, Pro and Cys than in coarse fibers. On the other hand, Imik and Gunlu (2011) have found that the elasticity, length and diameter of wool fibers were not significantly differed with sorghum uptake. The present correlation coefficients in Table (4) emphasized the former results which showed a significant positive correlation between amino acids; Cys, Ala, Glu, Pro and Met and FL while Cys and Pro achieved the same trend with CF and CS. On the contrary, Cys and Pro had a significant negative correlation with FCSA that means the increase of these two amino acids in wool fibers cause fineness and increase number of crimps / cm. These results have in conformity with the findings of Table (2). Moreover, FL was correlated with the rest of studied amino acids; Ser, Asp, Arg, Lys, Leu, Iso, Thr, His, Tyr, Gly, Val, Phe. The same trend is distinctly noticed for CS. It is noteworthy that cotting occurs in sheep fleeces with increasing of wool length (El-Sherbiny *et al*., 2006). As shown in Table (4), an increase in some amino acids in wool fibers such as Lys and Tyr can cause a decrease in CF and FCSA, respectively.

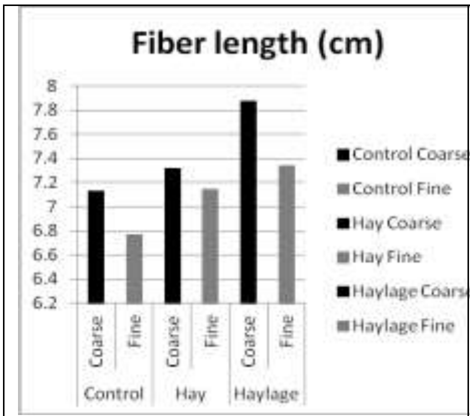

Fig.1: Fiber length in the different trial groups

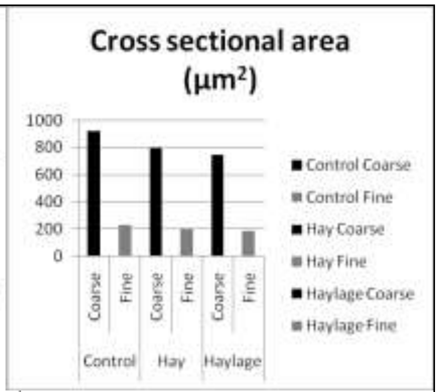

Fig.2: Fiber cross sectional area in the different trial groups

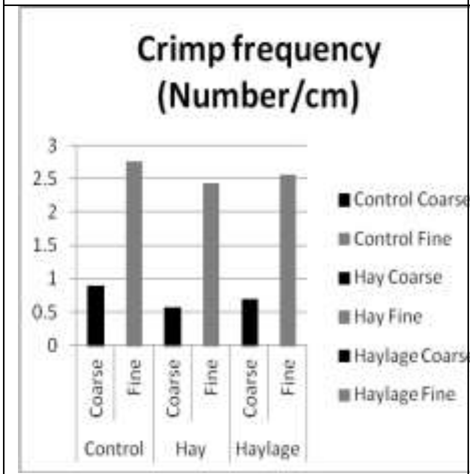

Fig.3: Crimp frequancy in the different trial groups

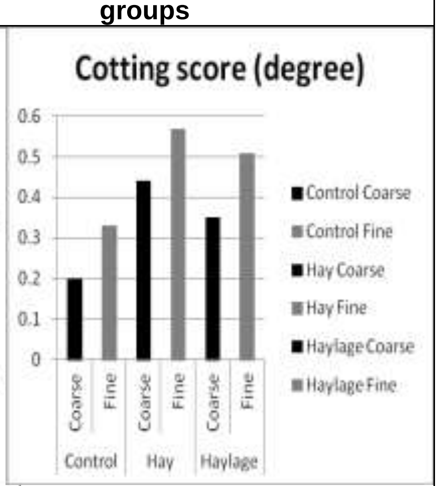

Fig.4: Cotting score in the different trial groups

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CONCLUSSION

The present study concluded that feeding on salt tolerant plants (*Kochia indica* and *Pennisetum americanum*) mixed with molasses may cause an increase in fiber amino acids contents specially Cysteine, Alanine, Glutamic acid, Proline and Metionine which in turn make changes in physical characteristics of wool fibers viz.; an increase in fiber length and cotting score, and a decrease in fiber cross sectional area and crimp frequency of Barki lambs.

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تـأثير التغذيـة علـى النباتـات المتحملـة للملوحـة علـى الخـواص الطبيعيـة والكيميائيـة لأليـاف الغطاء في الأغنام

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أجريت هذه الدراسة كإمتداد لتجربة سابقة من مشروع للتعاون التقني بعنوان "أنظمة إنتاج الأعلاف المتحملة للملوحة للأراضي المتأثرة بالأملاح في شبه جزيرة سيناء في مصر" والذى يدعمه المركز الدولي للزراعة الملحية (ICBA). كان الهدف من الدراسة هو تأثير التغذية على النباتات المتحملة للملوحة (الكوخيا والدخن) على بعض الخواص الطبيعية والكيميائية لألياف الغطاء في الأغنام. إستخدم فى هذه الدراسة أربعة وعشرين من ذكور الحملان البرقي النامية (متوسط أعمارها سته أشهر ومتوسط وزنها 18.08كجم) تم تقسيمها بشكل عشوائي إلى ثلاث مجموعات وغذيت علي مخلوط عليقة مركزة لتغطية 100% من احتياجاتها الحافظة. دريس البرسيم استخدم لتغذية المجموعة الأولى (ج1) كعليقة كونترول. الكمية الإجمالية من خليط الكوخيا والدخن تم تقسيمها إلى كميتين متساويين: الكمية الأولى تم حفظها على شكل دريس ليتم تغذية المجموعة الثانية (ج2)، في حين ان الكمية ألآخري تم خلطها مع المولاس بنسبة 5٪ (الهيلاج) لتغذية للمجموعة الثالثة (ج3) . تم أخذ عينات من الصوف لتقدير طول الألياف، مساحة مقطع الليفة، تكرار الثنيات (الكرمب)، درجة التلبد, كما تم تحليل الأحماض الأمينية الآتية بالألياف : الثريونين، الفالين، الميثيونين، الايزوليوسين، الليوسين، الفينيل الانين، الهستدين، الليسين, حمض الأسبارتيك، السيرين، حمض الجلوتاميك، البرولين، الجليسين، الالنين، السيستين، التيروزين والارجينين. أظهرت النتائج حدوث زيادة طفيفة في محتوي الألياف من جميع الأحماض الأمينية لكل من مجموعة الدريس (ج2) ومجموعة الهيلاج (ج3) مقارنة مع مجموعة الكونترول (ج1). سجلت النتائج وجود فروق ملحوظة في الأحماض الأمينية الالنين، السيستين، حامض الاسبارتيك، الأرجنتين، الثريونين والمثيونين بين المجموعات المختلفة. وأظهرت الأحماض الأمينية السيستين، الالنين، حامض الجلوتاميك زيادة معنوية في المجموعة الثالثة بينما المثيونين وحده حقق زيادة ملحوظة في المجموعتين الثانية والثالثة مقارنة بمجموعة الكونترول. الحمض الأميني الميثونين أزداد بشكل معنوي في الألياف الخشنة والناعمة لكل من المجموعتين الثانية والثالثة بينما الحمض الأميني الالنين إزداد فقط في الألياف الناعمة في المجموعة الثالثة مقارنة بالمجموعة الأولي (مجموعة المقارنة). لم يكن هناك اي تأثير معنوي للمعاملات علي صفات الصوف المدروسة باستثناء درجة التلبد والذي زاد بشكل معنوي في المجموعتين الثانية والثالثة مقارنة بالمجموعة الأولي. في داخل المجموعات حدثت زيادة طفيفة في طول الألياف الخشنة والناعمة في كلا من المجموعة الثانية والثالثة مقارنة بالمجموعة الأولي. الزيادة في طول الألياف الخشنة كانت زيادة معنوية مقارنة بالألياف الناعمة في المجموعتين الثانية والثالثة. نفس الاتجاه السابق تم ملاحظته علي درجة التلبد. انخفض مساحة مقطع الليفة في كلا من الألياف الناعمة والخشنة للمجموعتين الثانية والثالثة مقارنة بالمجموعة الأولي وهذا الانخفاض السابق كان عاليا في المجموعة الثالثة مقارنة بالمجموعة الثانية. التغذية علي الهيلاج يمكن ان تسبب زيادة في طول ونعومة الألياف عبر الانخفاض في مساحة مقطع الليفة وزيادة تكرار الثنيات (الكرمب) في الألياف الناعمة في المجموعة الثالثة مقارنة بالمجموعة الثانية وانخفاض نسبي في درجة التلبد. ونستخلص من هذه الدراسة ان التغذيه على خليط من نباتات الكوخيا والدخن المتحملة للملوحة والمعاملة بالمولاس (5%) قد أدى إلى زيادة فى محتوى الياف الصوف من الأحماض الأمينية تحت الدراسة والذى أدى ألى تغيرات فى الصفات الطبيعية لألياف الصوف لحملان أغنام البرقى.

قام بتحكيم البحث

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Table (1): Amino acids content (residue/100) in coarse and fine wool fibers for the different experimental groups

Amino Acids	G1			G2			G3			Pooled
	Coarse	Fine	Overall Mean	Coarse	Fine	Overall Mean	Coarse	Fine	Overall Mean	
Cys	3.13±0.22^{c}	3.86±0.22^{b}	3.50±0.16^{B}	3.49±0.22^{bc}	4.01±0.22^{ab}	3.75±0.16^{AB}	3.87±0.22^{bc}	4.58±0.22^{a}	4.23±0.16^{A}	3.83±0.16
Ala	4.01±0.26^{c}	4.10±0.26^{bc}	4.06±0.19^{B}	4.66±0.26^{abc}	4.73±0.26^{abc}	4.70±0.19^{A}	4.83±0.26^{ab}	4.91±0.26^{a}	4.87±0.19^{A}	4.60±0.19
Ser	7.77±0.47^{a}	8.21±0.47^{a}	7.99±0.34^{A}	7.92±0.47^{a}	8.64±0.47^{a}	8.28±0.34^{A}	8.01±0.47^{a}	8.80±0.47^{a}	8.41±0.34^{A}	8.23±0.34
Glu	14.31±0.79^{ab}	11.80±0.79^{b}	13.06±0.56^{A}	14.88±0.79^{a}	12.01±0.79^{b}	13.45±0.56^{A}	15.33±0.79^{a}	13.84±0.79^{a}	14.59±0.56^{A}	13.7±0.56
Asp	6.47±0.42^{b}	7.01±0.42^{ab}	6.74±0.30^{B}	6.97±0.42^{ab}	7.64±0.42^{ab}	7.31±0.30^{AB}	7.78±0.42^{ab}	8.03±0.42^{a}	7.91±0.30^{A}	7.32±0.30
Arg	9.08±0.56^{a}	9.12±0.56^{a}	9.10±0.40^{B}	9.42±0.56^{a}	9.79±0.56^{a}	9.61±0.40^{AB}	10.31±0.56^{a}	10.46±0.56^{a}	10.39±0.40^{A}	9.70±0.40
Lys	3.11±0.18^{ab}	2.76±0.18^{b}	2.94±0.13^{A}	3.46±0.18^{a}	2.80±0.18^{b}	3.13±0.13^{A}	3.55±0.18^{a}	2.91±0.18^{b}	3.23±0.13^{A}	3.10±0.13
Leu	6.64±0.39^{a}	6.69±0.39^{a}	6.67±0.28^{A}	6.71±0.39^{a}	6.78±0.39^{a}	6.76±0.28^{A}	6.77±0.39^{a}	6.87±0.39^{a}	6.82±0.28^{A}	6.75±0.28
Iso	4.88±0.30^{a}	5.17±0.30^{a}	5.03±0.21^{A}	4.93±0.30^{a}	5.44±0.30^{a}	5.19±0.21^{A}	5.00±0.30^{a}	5.53±0.30^{a}	5.27±0.21^{A}	5.16±0.21
Thr	6.22±0.37^{a}	5.81±0.37^{a}	6.02±0.26^{B}	6.67±0.37^{a}	6.22±0.37^{a}	6.45±0.26^{AB}	6.92±0.37^{a}	6.74±0.37^{a}	6.83±0.26^{A}	6.43±0.26
His	1.39±0.08^{a}	1.31±0.08^{a}	1.35±0.06^{A}	1.45±0.08^{a}	1.39±0.08^{a}	1.42±0.06^{A}	1.49±0.08^{a}	1.48±0.08^{a}	1.49±0.06^{A}	1.42±0.06
Pro	10.81±0.79^{c}	14.22±0.79^{ab}	12.52±0.56^{A}	11.97±0.79^{bc}	15.62±0.79^{a}	13.80±0.56^{A}	12.34±0.79^{bc}	15.87±0.79^{a}	14.11±0.56^{A}	13.5±0.56
Tyr	3.90±0.25^{b}	4.51±0.25^{ab}	4.21±0.18^{A}	3.98±0.25^{ab}	4.60±0.25^{ab}	4.29±0.18^{A}	3.99±0.25^{ab}	4.71±0.25^{a}	4.35±0.18^{A}	4.28±0.18
Gly	4.08±0.25^{a}	4.32±0.25^{a}	4.20±0.17^{A}	4.11±0.25^{a}	4.42±0.25^{a}	4.27±0.17^{A}	4.12±0.25^{a}	4.49±0.25^{a}	4.31±0.17^{A}	4.26±0.17
Met	0.77±0.05^{c}	0.69±0.05^{c}	0.73±0.04^{C}	0.93±0.05^{b}	0.76±0.05^{c}	0.85±0.04^{B}	1.21±0.05^{a}	0.89±0.05^{c}	1.05±0.04^{A}	0.88±0.04
Val	5.46±0.33^{a}	5.87±0.33^{a}	5.67±0.23^{A}	5.49±0.33^{a}	5.88±0.33^{a}	5.69±0.23^{A}	5.57±0.33^{a}	5.90±0.33^{a}	5.74±0.23^{A}	5.70±0.23
Phe	3.12±0.18^{a}	2.89±0.18^{a}	3.01±0.13^{A}	3.17±0.18^{a}	3.01±0.18^{a}	3.09±0.13^{A}	3.20±0.18^{a}	3.16±0.18^{a}	3.18±0.18^{A}	3.09±0.18

G1: Control group, G2: Hay feeding group, G3: Haylage feeding group.
Capital super script means differences between overall means. Small super script means differences between fine and coarse fibers

Table (4): Simple correlation coefficients between analyzed fiber amino acids and some physical characteristics of wool fibers for the different experimental groups

Items	Cys	Ala	Ser	Glu	Asp	Arg	Lys	Leu	Iso	Thr	His	Pro	Tyr	Gly	Met	Val	Phe
FL cm	0.58*	0.82***	0.82***	0.78***	0.8***	0.90***	0.77***	0.97***	0.80***	0.93***	0.96***	0.53*	0.62**	0.84***	0.62*	0.85**	0.97**
FCSA μm^2	-0.50*	0.01	0.20	0.75***	-0.18	0.05	0.76***	0.18	-0.23	0.39	0.36	-0.68**	-0.47*	-0.16	0.47*	-0.13	0.46
CF n/cm	0.69**	0.19	0.61***	-0.47	0.44	0.28	-0.51*	0.32	0.64**	-0.08	0.02	0.87***	0.83***	0.62**	-0.43	0.60**	-0.02
CS grades	0.78***	0.41	0.76***	0.09	0.77***	0.66 ***	0.12	0.55*	0.75***	0.51*	0.53*	0.84***	0.75***	0.69***	0.19	0.64**	0.43

***P<0.05, ** P<0.01, *** P<0.001, shadow columns represents the amino acids which significantly affected by the treatment.**