American-Eurasian J. Agric. & Environ. Sci., 3 (4): 561-567, 2008
ISSN 1818-6769

Effect of Pre-Weaning Diet on Lamb's Rumen Development

G.A. Abou Ward

Department of Animal Production, National Research Center, Dokki, Giza, Egypt

Abstract: Twenty eight Ossimi male lambs, with an average live body weight 4.75 kg and 7 days age were randomly assigned to two feeding groups each of 14 animals to study the effect of pre-weaning diet on lamb's rumen development. Both the two groups suckled their dams until being weaned at 12 weeks of age (natural weaning). The first group depended completely on dam's milk as a solely available feed (control), while the other was supported by a starter ration which found the nutritive value to be 19.1% CP (14.5% DCP) and 81.0 TDN, besides dam's milk. Supporting natural weaned lambs with creep feeding at an earlier age influenced ($p>0.05$) length of the alimentary canal, however different intestinal segments maintained to keep constant ratios. The small intestine represented the major length (about 80% of the total length). Supporting lambs with creep feeding rations led also to higher volume displacement. However, different stomach compartments maintained to keep constant volumes. As shown the rumeno-reticulum indicated the higher volume capacity (nearly 80-84%).Natural weaned lambs, depended solely on rearing milk, had higher ($p>0.05$) abomasum volume in comparison with the creep-feeding one. On contrast creep fed group tended to have higher ($p>0.05$) rumino-reticulum volume capacity. Supporting rearing lambs with creep feeding at an earlier age (2wks) improved ($p>0.05$) ruminal papillary, being longer with more surface area in comparison with the solely feeding milk group.

Key words: Pre-weaning · Starter · Lamb's · Rumen · Development

INTRODUCTION

Proper development of the rumen is an important task that can be controlled to benefit both the newborn calf, lamb and the producer. Normally, weaned ruminants might lose some weight when change liquid feed to solid feed because of undeveloped rumen. The process of rumen development does not occur "magically" and with the right management the cost of raising calves and lambs can be decreased [1].

The rumen of a newborn ruminant animal is a small, nonfunctional sac, accounting for less than 30% of the total stomach mass and displaying rudimentary papillary development [2], but the rumen of a mature sheep accounts for up to 80% of the stomach mass and possesses numerous long papillae. In addition the increase in papillary development, the epithelium that lines the rumen becomes keratinized during the morphological development of this organ. Several metabolic changes also occur in the rumen epithelium in concert with morphological development, including decreased glucose oxidation, increased VFA oxidation and increased production of ketone bodies from butyrate [3, 4]. The mechanisms that are responsible for rumen development has not been completely characterized; however, solid feed consumption stimulates rumen morphological development [5]. Also, Davis and Drackley [6] reported that, important component in successful newborn rearing programs is an early transition to starter grain. Anderson *et al*. [7] concluded that development of rumen papillae is aided by the fermentation of newborn starter to VFA. Growth of rumen papillae aids in allowing the newborn to change from mono-gastric form to one characteristic of adult ruminants [8]. When young animals consume both starter and water at an early age, maturation of the rumen occurs at an earlier age compared with milk feeding alone. Lane and Jesse [9] found that, calves fed milk alone show little rumen development, but those fed milk plus solid feed show a marked increase in rumen volume and weight, as well as exhibiting increased papillary length and density.

The aim of the present study was to justify the effect of pre-weaning diet on rumen development of local weaned lambs through a comparable study between two lamb groups weaned naturally at 12 weeks. The first group depended solely on suckling their dams, while the second was supported by a creep feeding ration, in addition to suckling their dams.

Corresponding Author: Dr. G.A. Abou Ward, Department of Animal Production, National Research Center, Dokki, Giza, Egypt

MATERIALS AND METHODS

Animals Management and Experimental Rations: Twenty eight Ossimi male lambs, with an average live body weight 4.75 Kg and 7 days age were randomly assigned to two feeding groups each of 14 animals. Both the two groups suckled their dams until being weaned at 12 weeks of age (natural weaning). The first group depended completely on dam's milk as a solely available feed T_1 (control), while the other was supported by a starter ration $_{T2}$ (14.5% DCP and 81.0% TDN value), besides dam's milk.

Experimental rations were formulated and calculated according to NRC recommendations [10] and offered to lambs *ad libitum*. The starter composition and chemical analyses were presented in Table 1.

Anatomical and Histological Studies of the Digestive System: Four fasted animals (12 weeks old) from each feeding group were randomly chosen and slaughtered. Animals were then skinned, evacuated and the hot carcass weight was recorded.

Anatomical Techniques: The digestive tract of the slaughtered animals was immediately removed by severing the esophagus which was tied at the cardia. The gastrointestinal tract was segmented by ligatures into rumen, reticulum, omasum, abomasum, small intestine, caecum, colon and rectum according to Sisson and Grossman [11].

Anatomical Measurements: Each segment of the tract was emptied from its digsta content. The segment was then cleaned gently by a tap water, while it's clean fresh tissue was weighed and volume capacity of each compartment was measured. Length of the intestinal segments was also measured.

Volume Capacity: Volume capacity of different stomach compartments (rumen, reticulum, omasum and abomasum) were measured by using the water filling method employed in the study of Abd-El-Khalek [12], where one opening of the part was tied and filled with water through the other opening side, while it was placed on a solid surface. It was ensured that no air bubbles remained in the compartment.

Fresh Tissue Weight: Cleaned fresh tissue weight of each of the stomach compartments were recorded to the nearest gram.

Table 1: Composition of creep feeding ration offered to natural reared lambs from 2-12 weeks old (DM basis)

Type of weaning	Natural rearing 12 wk, (NR)	Natural rearing (NR)+Starter (St)	Current price
Ration composition (%)	T_1	$_{T2}$	L.E /ton
Yellow Corn	-	55.0	500
Soybean meal	-	30.0	950
Wheat bran	-	7.0	400
Molasses	-	5.0	240
Lime stone	-	1.5	50
Salt	-	1.0	100
Mineral mix. and Vit. (Premix)*	-	0.5	12000
Price LE / Ton	-	663.8	-
DCP (%)	-	14.5	-
TDN (%)	-	81.0	-

Chemical composition

DM	OM	CP	EE	CF	NFE	Ash
90.9	93.8	19.1	3.1	4.4	67.2	6.2

*Primex, contained/kg Mn. 33 mg, Zn 25 mg, Fe 20 mg, Cu 6 mg, I 800 mg, Sel 66 mg and Co 160 mg

Histological Studies

Samples and Histological Techniques: Samples were taken from 4 animals of each group from different portions of the rumen.

Samples were immediately fixed in 10% formalin saline (9 gram NaCl in 1 L) for 24 h; following this, samples were washed by running water for 24 h. Dehydration was carried out by ascending graded series of ethyl alcohol 60, 70, 80, 90 and 95% (24 h in each grade) and 100% (12h). Toluene was used as clearing agent for (8-10 h). The samples were impregnated in three successive baths of melted paraffin wax (55-58°C) for 2 h. Each piece of samples were embedded in paraffin wax and finally cut into sections, 4-5 μ thick. The sections were stained by haemytoxelin and eosin, followed for general studies according to Bancroft and Stevens [13].

Histological Examination: Sections were prepared and examined microscopically and different criteria were measured, using a micrometer eye piece. Each measurement in every region was replicated 40 times (4 animals X 10 times for each animal) according to Salama [14]. Parameters were recorded either in micron or in millimeters. The general features of the inner surface of the rumen was examined.

Rumen Papillae

Density of the Rumen Papillae: Samples, each about 5 cm² were collected from 10 regions, representing the surface area of the anterior ventral sac of the rumen to estimate the density of the papillae. The papillae density was obtained by counting the total number of papillae in the field of a dissecting microscope in each region. The area of the field was obtained as usual by micrometer stage.

Length of The Rumen Papillae: Thirty papillae in 10 different locations covering the area of the anterior ventral sac were separately measured for their length by a micrometer apparatus.

Circumference and Cross-sectional Area of Papillae: The average circumference of 20 papillae in each case was obtained by measuring the contour line of each papilla, using a curvimeter on an image of cross-section from a micro projector.

Surface Area of Papillae: The length of the papillae and the average circumference represent the dimensions of a cylindrical shape. Thus, the mean surface area of papillae was calculated. Taking the diameter at the mid length compensates for the slight tapering towards the free end; in any case the papillae were not conical but rather a compressed cylinder.

The total papillary area per 1 cm² of the ventral sac was computed by the product of the mean papillae surface times and the mean number (density) of papillae per 1 cm² of the same area.

The Inter Papillary Area: The average cross section area of the papillae was computed by obtaining the average diameter from the circumference measure. Within 1 cm² of the rumen surface (ventral sac), the area covered by papillae was a measurable from the density X cross-sections area. Thus the inter papillary area was obtained.

The Total Absorption Surface: The absorbing surface within 1cm² of the ventral sac of the rumen is the total papillary area in 1cm² of the tissue plus the inter papillary area.

Statistical Analysis: Data were analyzed using the general linear models procedure adopted by SAS [15]. Difference between means was tested for significance using the L.S.D test according to Duncan [16]. One way analysis of variance was adopted using the following equation:

$$Yij = u + Ti + Eij$$

Where:

Yij = The observations of the parameter measured.

U = Overall means

Ti = The effect of replication

Eij = The random error term.

RESULTS AND DISCUSSION

Chemical Composition of the Starter: Chemical composition of starter are shown in Table 1 and the nutritive value of starter was found to be 19.1% CP (14.5% DCP) and 81.0% TDN, the matter which coincide with NRC recommendations [10] for the features of creep feeding rations of newborn lambs; being palatable and enriched with higher caloric and protein contents, while the protein must be of higher biological value for raising lambs in their early life.

Effect of Pre-weaning Diet on the Development of the Alimentary Tract Segments: Data presented in Table 2 showed longer ($P<0.05$) small intestine for T_2 in comparison with those of T_1, *i.e* 24.01 *vs* 21.93 meter, respectively. In both groups the small intestine comprised a constant length (80% relative to the total length). Similar length percentages relative to the whole length of the small intestine for different parts of the alimentary canal and within both the two treated groups. This matter may suggest that different parts of the alimentary tract had a constant length relative to the small intestine and regardless of the external effects.However, the higher ($P<0.05$) length of the small intestine for the T_2 may be a resultant effect to the solid fed administrated to such group, which led to stretch its length. Stimulating the functional role of the alimentary canal at an early age seems to increase its length.

According to Wallace [17] the growth rate of the visceral organs developed more or less in the order of their functional importance. Moreover, defined three main factors acting singly or in combination to influence the acceleration in growth rate of such organs, being weight of sheep, age and plane of nutrition. Also, Baldwin *et al*. [18] reported that less consumption of solid feed by the calves fed milk *ad lib* is associated with poor performance post-weaning, probably because of delayed ruminal development. On the other hand Khan *et al*. [19] concluded that the calves on restricted milk feeding consumed more solid feed compared with those fed milk conventionally. Provision of milk to

Table 2: Effect of pre-weaning diet on the relative length percentages of the alimentary tract segments of Ossimi male lambs at (12 wks of age)

Item	Segments of the alimentary tract					
Pre-weaning Diet	Total length of the Ints. (m)	Small Ints. (%)	Col. (%)	Caec. (%)	Rect. (%)	Oes.(%)
T_1 (NR)*	21.93b	80.3	16.7	0.86	0.61	1.53
T_2 (NR + St)**	24.01a	81.0	15.9	0.90	0.63	1.57
±SE	±15	±3.75	±1.98	±0.15	±0.13	±0.07

a and b: Means in the same column with different superscripts are significantly different (P=0.05). Ints: small intestine. Col: colon. Caec: caecum Rect: rectum. Oes: esophagus. St**: starter. NR*: Natural rearing (12 wks of age)

Table 3: Means±SE and percentages of the length of alimentary tract segments for Ossimi male lambs at 12 wks slaughter age as affected by pre-weaning diet relative to neonatal lambs (0-wk) and adult animals

	Segments of the alimentary tract							
Item	Total length of the Ints (%)		Small Ints%		Col.%		Caec.%	
Preweaning diet	0	Ad	0	Ad	0	Ad	0	Ad
T_1 (NR)	231.0b	82.6b	220	87.3	315.0	65.2	335.0	62.7
T_2 (NR + St)	243.0a	86.9a	242	92.9	310.0	64.0	402.0	74.7
±SE	±1.7	±2.6	±4.5	±1.8	±34.0	±3.2	±19.0	±4.0

a and b: Means in the same column with different superscripts are significantly different (P=0.05). O = newborn lambs. Ad = adult animals

Table 4: Effect of pre-weaning diet on the relative percentages of stomach volume capacity for Ossimi male lambs at (12 wks of age)

Item	Stomach compartments				
Pr-weaning Diet	Total volume capacity of stomach in (cm3)	Rumen (%)	Retcum (%)	Omasum (%)	Abomasum(%)
T_1 (NR)	5529b	72.4	8.8	2.4a	15.9a
T_2 (NR + St)	10196a	73.8	10.1	1.3b	13.3b
±SE	±291	±1.4	±1.0	±0.12	±1.1

a and b: Means in the same column with different superscripts are significantly different (P = 0.05)

calves using the step-down method could prevent the problems of depressed solid feed consumption associated with *ad lib* milk intake and of poor rumen development. Percentages of the whole alimentary canal and its segments relative to both the newborn lambs and the adult animals favored the creep-fed group had more (P<0.05) lengths in comparison with the milk – fed group, in either the total alimentary canal or within the alimentary canal segments. The total length of the small intestine as shown in (Table 3), being 243 times that of the newborn lambs in T_2 *vs* only 231 times that of T_1 and relative to the adults; lambs of T_1 had 82.6% lower (P<0.05) length *vs* 86. 9%, relative to the adult ones for lambs of T_2.

Similar rate percentages for different alimentary canal segments are shown in favor of T_2, indicating an activating and promoting effects due to plane of nutrition applied to such group.

Effect of pre-weaning diet on volume capacity: Data presented in Tables 4 and 5 showed the effect of pre-weaning diet on the stomach volume capacity of experimental animals and their relationships to both the newborn lambs and the adults. The effect of nutritional regimen on the volume capacity of experimental lambs was more pronounced (P<0.05) in favor of creep – feeding group, *ie* 10196 cm^3 *vs* 5529 cm^3 for lambs of T_2 and T_1, respectively. This might be due to the feeding starter to lambs of T_2. However, the rumen volume and different compartments (Reticulum, omasum and abomasum) had nearly constant volumes within the same experimental group. On the other hand, T_1 had in general higher (p<0.05) omasum and abomasum volumes due to lambs in this group depended completely on dam's milk. Such results agreed well with the earlier reports of Wallace [17]; that the organs developed more or less in the order of their functional importance and also with the findings of

Table 5: Means±SE and percentages of the stomach volume capacity for Ossimi male lambs at 12 wks slaughter age as affected by pre-weaning diet relative to neonatal lambs (0-wk) and adult animals

	Stomach compartment (%)							
	Total vol. Capac		Rum – retc.		Om.		Ab.	
Item	0	Ad	0	Ad	0	Ad	0	Ad
T1 (NR)	1195b	42.6b	5696b	41.7b	211.1	28.6b	267b	52.7b
T_2 (NR + St)	2200a	78.4a	10879a	79.7a	227.0	30.1a	425a	83.9a
±SE	±64.6	±2.4	±336.4	±2.4	±4.8	±0.8	±0.9	±0.4

a and b: Means in the same column with different superscripts are significantly different (P = 0.05)

Table 6: Effect of pre-weaning diet on the relative weight percentages of stomach compartments for Ossimi male lambs at (12 wks. of age)

Item	Stomach compartment				
Pre-weaning diet	Total stom.Wt. (gm)	Rum. (%)	Retc. (%)	Om. (%)	Ab.(%)
T_1 (NR)	1353	70.2b	6.2b	4.3	10.4
T_2 (NR + St)	1500	82.0a	12.4a	7.2	7.6
±SE	±50	±2.5	±0.8	±3.4	±3.6

a and b: Means in the same column with different superscripts are significantly different (P = 0.05)

Table 7: Means±SE percentages of fresh tissue weights of stomach compartments of Ossimi male lambs at 12 wks slaughter age as affected by pre-weaning diet relative to neonatal lambs (0-wk) and adult animals

	Stomach compartment (%)							
	Total stom.wt.		Rum – retc.		Om.		Ab.	
Item	0	Ad	0	Ad	0	Ad	0	Ad
T_1 (NR)	591a	69.6a	1470a	82. 7a	248b	20.7b	83b	37b
T_2 (NR + St)	533b	62.2b	1240b	69.4b	380a	36.1a	102a	46a
±SE	±12	±1.2	±18	±1.73	±22	±2.10	±3. 7	±2.8

a and b: Means in the same column with different superscripts are significantly different (P = 0.05)

Table 8: Effect of pre-weaning diet on the ruminal papillary length, circumference, density, surface area and total papillary surface area of Ossimi male lambs at 12 weeks slaughter age in comparison with neonatal lambs and adults

Item	Length (mm)	Circumference (mm)	Density (No/cm2)	Surface area (mm2) S.A/P *	Total papillary surface area (mm2/cm2) T.S.A **
Birth	0.44d	--	3168a	--	--
T_1 (NR)	1.15c	1.75c	180 b	2.1c	362c
T_2 (NR + St)	2.24b	2.83b	117b	6.4b	742b
Adult	4.47a	3.92a	75b	17.5a	1314a
±SE	±0.15	±0.03	±26	±0.8	±64

a, b, c and d: Means in the same column with different superscripts are significantly different (P = 0.05)

* S.A/P = Mean surface of single papillae [circumference × length].

** T.S.A = Total surface area of papillae/cm2 of rumen surface (S.A. / PXNo. of P. /cm)

Wardrop and Coombe [20], as the abomasum had the fastest growth rate of all the four stomachs during the first week after birth, but by 21 days of age the rumen was the larger and then the rumen increased at faster rates, but the abomasum remained almost static.

In the light of the present results, it could be concluded that the nature of available feed introduced to newborn lambs affected and promoted significant activation to the functional organ.Relative to newborn lambs (0 days) and the adults (Table 5), the similar trends were also expressed, since lambs of T_2 had 2200 higher (P<0.05) volume capacity and 78.4% of that of the adults *vs* 1195 and 42.6% for lambs of group T_1. However, within each group the fresh rumen tissue weight and abomasum fluctuated and had a pronounced weight value relative to its functional role.

Data obtained in Tables 6 and 7 showed heavier ($P<0.05$) stomach weight for lambs supported with creep feeding ration in comparison with milky–fed group 1500 *vs* 1353 gm/head, respectively.Creep- fed group had heavier ($P<0.05$) rumen fresh weight (82%) relative to the total fore-stomach weight in comparison with only 70.2% for the solely milk–fed group. On contrast, the milky–fed group had heavier, but insignificant abomasum fresh weight which coincides with its function. The similar percentage ratios are shown relative to both newborn and adults (Table 7). The present results were in complete agreement with the theoretical opinion of Wallace [17] and with the findings of Wardrop and Coombe [20], either in the relative percentages of different compartments of the fore-stomach or relative to the functional role of each compartment due to the plane of nutrition on the development of ruminal compartments. According to the study of Wardrop and Coombe [20], the rumen fresh weight weighed 400g, reticulum 66, omasum 45 and the abomasum 145g, respectively for 84 days slaughtered Border Leicester × Merino lambs.

Effect of Pre-weaning Diet on Ruminal Papillary Development: Data presented in Table 8 showed shorter ($P<0.05$) papillary length (0.44 mm) in newborn lambs (0-time), reached to (4.47 mm) in the adults. The papillary length in the present study was in favor of T_2 group (2.24 mm *vs* 1.15 mm for T_1). Higher ($P<0.05$) circumference (mm), surface area (mm²) and total papillary surface area were noticed for T_2 in comparison T_1. This result was due to the introduction of solid- feed for lambs of T_2, which enhanced the production of VFA's, which in turn activated the papillary development of such group biologically and functionally [21]. Similar results were reported by Warner *et al.* [22], who showed that the mechanisms that are responsible for rumen development have not been completely characterized; however, solid feed consumption stimulates rumen morphological development. Calves fed milk alone show little rumen development, but those fed milk plus solid feed show a marked increase in rumen volume and weight, as well as exhibiting increased papillary length and density. Density of ruminal papillae were found to be more numerous ($P<0.05$) in newborn lambs and decreased ($P<0.05$) with the advanced ages (Table 8). However, papillary density had also a reverse relationship with length, functional role and enlargement as shown by Warnner *et al.* [22]; Tamate *et al.* [23] and Hubber [24].

In the light of the present results, creep-feeding lambs had longer papillary length, circumferance, total papillary surface area, but lower ($P<0.05$) density / cm², indicating more activation and development role in comparison with the solely milk- fed group.

REFERENCES

1. Quigley, J.D., 1996. Growth, intake and behavior of calves fed milk replacer by nipple bottle or computer feeding system. Pro. Anim. Sci., 12: 187.
2. Church, D.C., 1969. Digestive physiology and Nutrition of ruminants. Vol. 1. D. C. Church publishing Corvallis, OR. (cited by Lane and Jesse (1997) Effect of volatile fatty acid infusion on development of the rumen epithelium in Neonatal sheep., J. Dairy. Sci., 80: 740-746.
3. Baldwant, S., K. Chaudhary and S. Gill, 1992. Developmental changes in the stomach of Murrah buffalo calves. Buffalo J., 9: 195-201.
4. Heitmann, R.N., D.J. Dawes and S.C. Sensenig, 1987. Hepatic Ketogenesis peripheral Ketone body utilization in the ruminant. J. Nutr., 117: 1174-1180.
5. Warner, R.G. and W.P. Flatt, 1964. Anatomical development of the ruminant stomach. In physiology of Digestion in the Ruminant P.24.R.W. Dougherty, R.S. Allen, W. Burroughs, N.L. Jacobson and A.D. McGilliard, des. Butter worths, Washington D.C.
6. Davis, C.L. and J.K. Drackley, 1998. Starter feed: Importance, composition and intake in the Development, Nutrition and Management of the Young Calf. Iowa State University Press, Ames, pp: 283-206.
7. Anderson, K.L., T.G. Nagaraja and J.L. Morrill, 1987. Ruminal metabolic development in calves weaned conventionally or early. J. Dairy Sci., 70: 1000-1005.
8. Warner, R.G., 1961. Is hay required to develop rumen capacity? J. Dairy Sci., 44: 1177.
9. Lane, M.A. and B.W. Jesse, 1997. Effect of volatile fatty acid in fusion on development of neonatal sheep *Rumen epithelium*. J. Dairy Sci., 80: 740-746.
10. NRC 1985. National Research Council "Nutreint Requirements of sheep 6th the revised. Edn. Nat Acad. Press, Washington, D.C., USA.
11. Sisson, S. and J.D. Groassman, 1969. The Anatomy of the Domestic Animals. 4th Edn. W.B. Saunders Co. Philadelphia and London.
12. Abd-El-Khalek, A.E., 1986. Comparative study of the digestive system in sheep and goats. M.Sc. Thesis Faculty. Agric., Mansoura University, Egypt.

13. Bancroft, J.D. and A. Stevens, 1982. Theory and practice of histological techniques 2nd Edn. Bancroft, J.D. and A. Stevens (Eds.). Churchill Livingstone, London [Cited by Omran (1990) comparative study of the development and function of digestive system in sheep Goats. Ph.D. Thesis. Fac. Agric. Assiut Univ., Egypt.
14. Salama, M.A., 1986. physiological studies on digestive performance in buffalo calves. Ph.D. Thesis. Fac. Agric. Zagazig Univ. (Banha branch), Egypt.
15. SAS., 1996. Statistical Analysis System, SAS user's Guide: statistics. SAS institute Inc. Editors, cary, NC.
16. Duncan, D.B., 1955. Multiple Range and Multiple F-test Biometrics, 11: 42.
17. Wallace, L.R. 1948. J. Agric. Sci., 38: 243. (Cited by Godfrey, N.W. 1961) The functional development of the calf. I-Growth of the stomach of the calf. J. Agric. Sci., 57: 173-175.
18. Baldwin, R.L., VI, K.R. McLeod, J.L. Klotz and R.N. Heitmann, 2004. Rumen development, intestinal growth and hepatic metabolism in the pre- and post-weaning ruminant. J. Dairy Sci. 87(E Suppl.):E55–E65.
19. Khan, M.A., H.J. Lee, W.S. Lee, H.S. Kim, S.B. Kim, K.S. Ki, J.K. Ha, H.G. Lee and Y.J. Choi, 2007. Pre- and Post-weaning Performance of Holstein Female Calves Fed Milk Through Step-Down and Conventional Methods J. Dairy Sci., 90: 876-885.
20. Wardrop, I.D. and J.B. Coomb, 1960. The postnatal growth of the visceral organs of the lamb. I. the growth of the visceral organs of the grazing lamb from birth to sixteen weeks of age. J. Agric. Sci., 54: 140-143.
21. Coverdale, J.A., H.D. Tyler, J.D. Quigley and J.A. Brumm, 2004. Effect of Various Levels of Forage and Form of Diet on Rumen Development and Growth in Calves J. Dairy Sci., 87: 2554-2562.
22. Warner, R.G., W.P. Flatt and J.K. Loosli, 1956. Dietary factors influencing the development of the ruminant stomach. J. Agric and Food Chem., 4: 788-792.
23. Tamate, H., A.D. McGilliard, N.L. Jacobson and R. Getty, 1964. The effect of various diets on the histological development of the stomach in the calf-Tohoku. J. Agric. Res., 14: 171.
24. Hubber, J.T., 1969. Development of the digestive and metabolic apparatus of the calf. Symposium: calf nutrition and rearing. J. Dairy Sci., 52: 1303-1311.