Longitudinal investigations of anatomical and morphological development of gastrointestinal tract in goats from colostrum to post-weaning

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Our Goal

What are the morphological and anatomical changes in the gastrointestinal tract and other organs from the pre-ruminant to ruminant stage?

Background

Laiwu Black Goat

- Famous local breed in China
- Resistance to rough feeding
- Disease resistance
- Delicious meat
- High fecundity

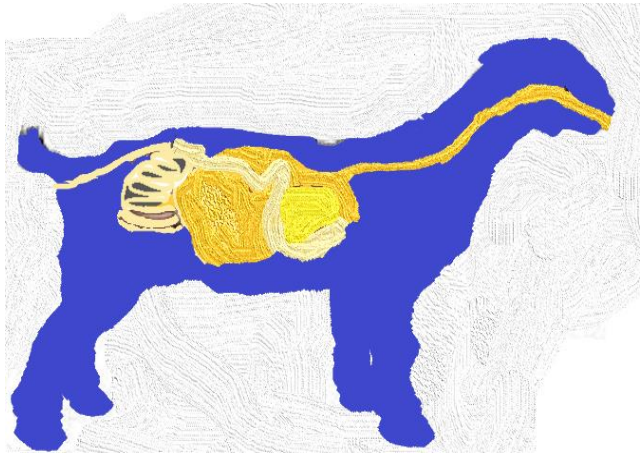
The demand for improving the quality and productivity of goats

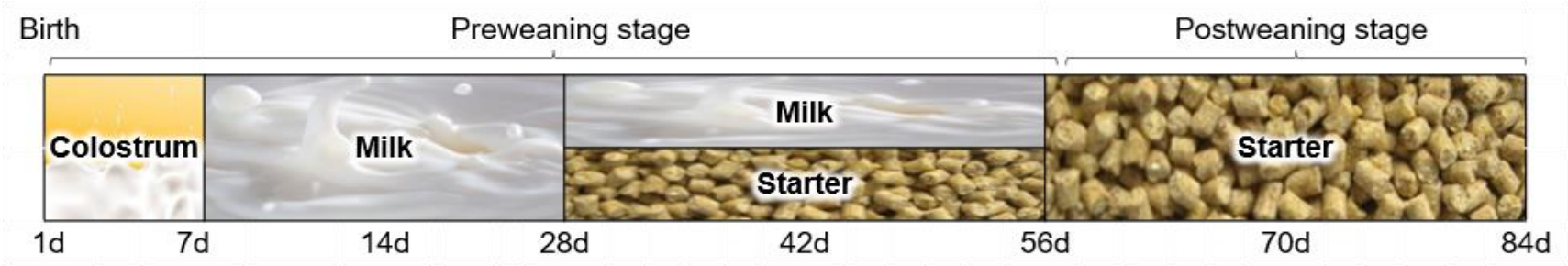
China with high population and economic growth

The digestive tract development Importance and long-term impact

- Digestion and absorption function.
- Growth performance.
- Administration of the weaning stage.
- Avoid challenges in livestock production.
- Health status.
- Industrial development.

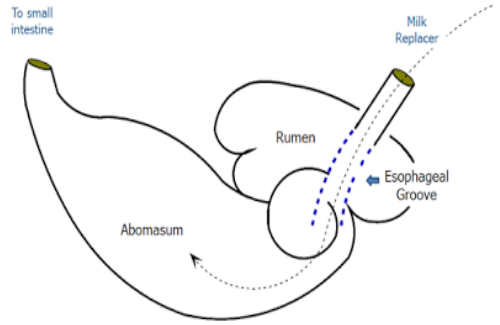
The digestive tract after birth exhibited morphological, biochemical, and ultrastructural changes that contribute to its maturation [1].

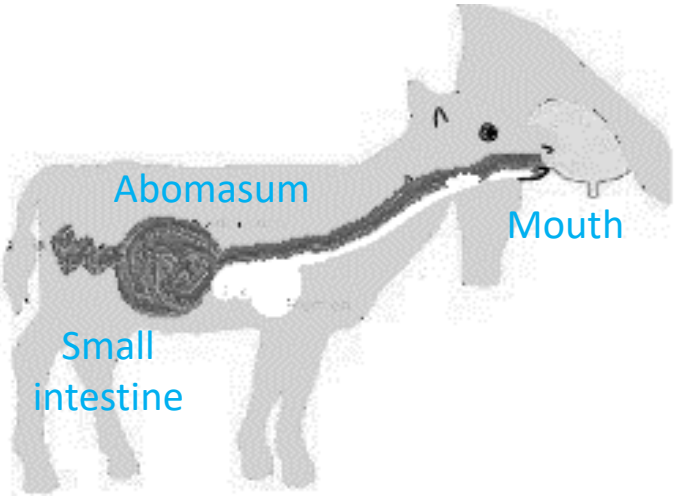




Digestive tract development

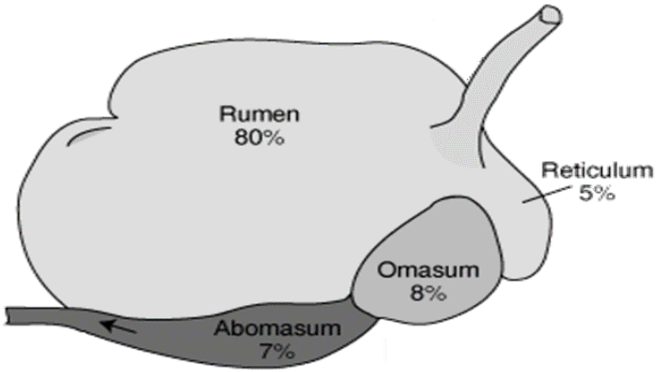
Liquid stage

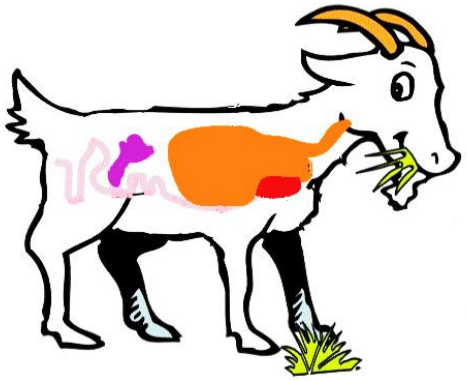




Blättler, et al. [2] showed the improvement of small intestine development in neonatal calves fed colostrum.

Solid feed stage





Rumen development and VFA production stimulated by solid feed intake promoted the nutrient availability in the intestine and its morphology development [9].

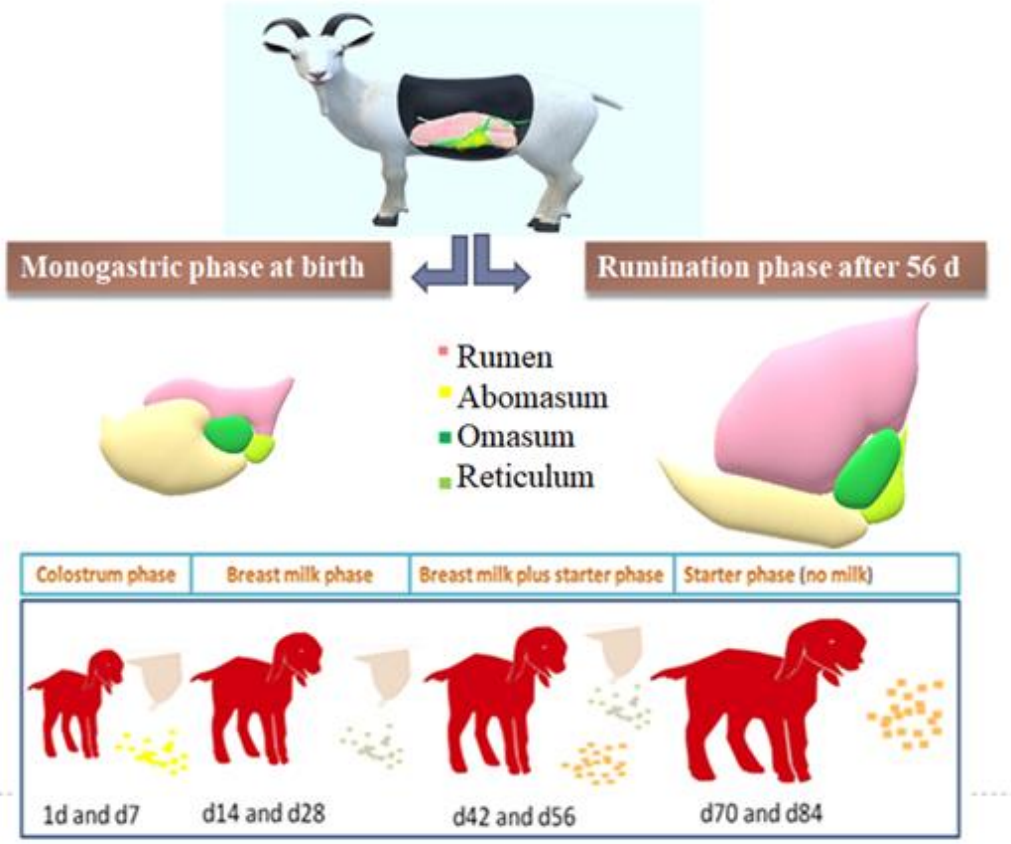
Digestive tract development

The research questions

- The stage development of rumen morphology of Laiwu Black Goat and its association with the longitudinal dietary changes from liquid to solid, and its relationship with the phase development of small and large intestine, as well as other organs such as liver and kidney, are not well-known in the literature.

Study design

This study used eight-time points from birth to 84 d of age to explore the anatomical and morphological development of the gastrointestinal tract and the growth performance of Laiwu Black Goat kids.



Abdelsattar *et al.*, Animals 11 (3): 757 (2021)

Tracking goats' development over time

Forty-eight healthy female goats of different ages (1, 7, 14, 28, 42, 56, 70, and 84 d old) were randomly selected.

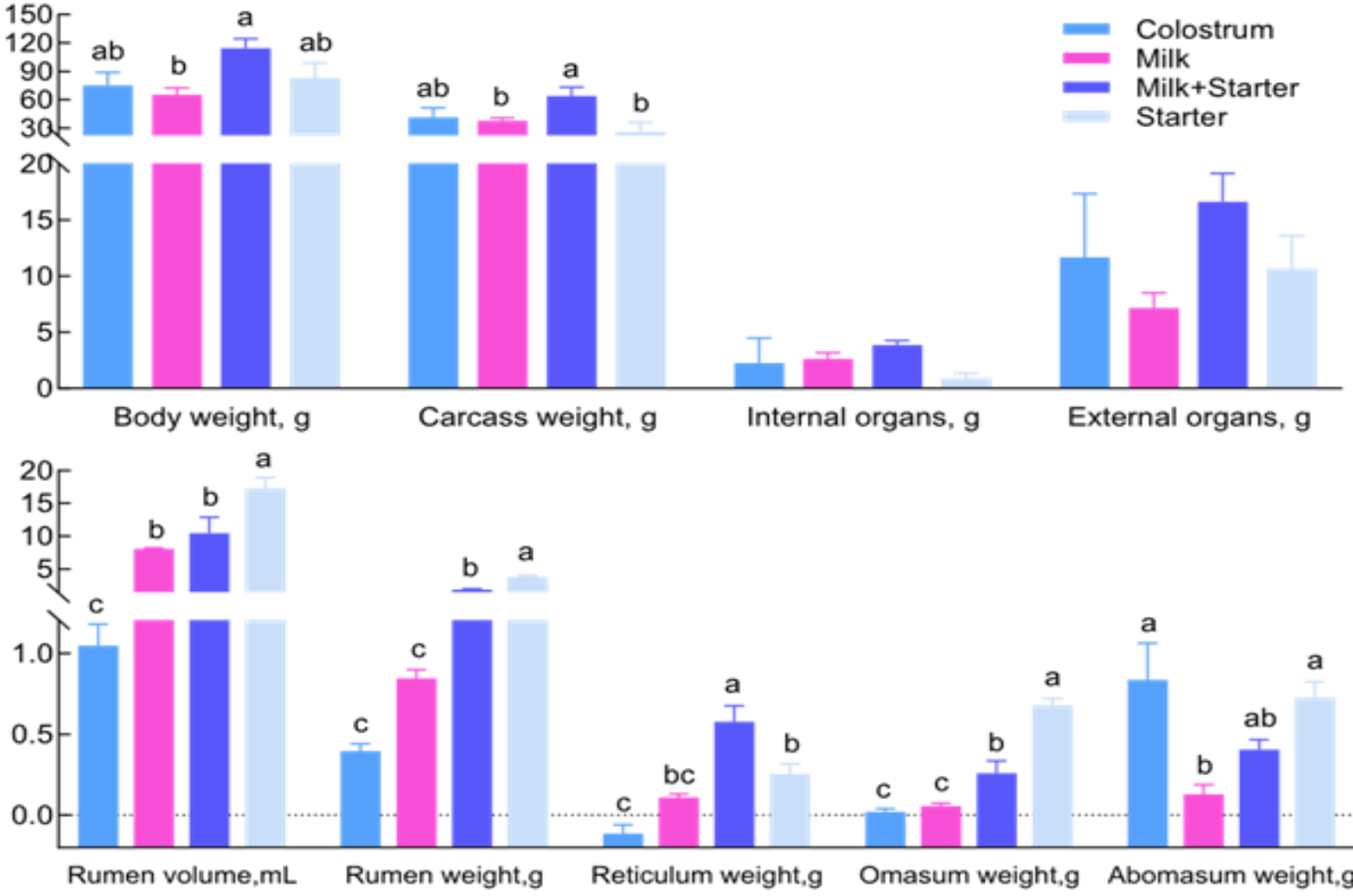
After birth, goats were housed in well-ventilated pens with their dam and at d60, the goats were separated from their dams and transferred into individual pens.

The live body weight, body size indices, carcass, organ, dressing percentage, stomach anatomy, gastrointestinal histomorphology were determined.

The data analysis was performed by one-way ANOVA using IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL).

R E S U L T S

The absolute growth rate



The absolute growth rate

Growth Performance and Carcass Measurements

Table 1. Body and carcass weight (kg) and body size indices (cm) from colostrum to post-weaning in goats (n = 47).

	Diets[1]											
	MC		MM		MMSD		SD			*P*-value		
Items1	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Body weight	2.91^{e}	3.43^{de}	4.36^{de}	4.80^{d}	6.66^{c}	8.00^{bc}	8.89^{ab}	10.3^{a}	0.41	<0.01	0.90	0.82
Carcass weight	1.40^{d}	1.68^{cd}	2.23^{cd}	2.47^{c}	3.59^{b}	4.25^{ab}	4.36^{ab}	4.97^{a}	0.21	<0.01	0.32	0.72
Dressing %	47.5^{b}	49.2^{ab}	50.8^{ab}	51.5^{ab}	52.7^{a}	52.7^{a}	49.1^{ab}	48.0^{ab}	0.55	0.99	<0.01	0.74
Body oblique length	28.7^{d}	29.9^{d}	33.6^{cd}	37.6^{c}	43.1^{b}	44.7^{ab}	45.7^{ab}	49.5^{a}	1.20	<0.01	0.05	0.65
Height	31.4^{d}	31.7^{d}	33.8^{d}	35.3^{cd}	38.7^{bc}	41.4^{ab}	42.2^{ab}	44.5^{a}	0.83	<0.01	0.55	0.72
Cannon bone circumference	6.10^{c}	6.50^{bc}	6.83^{abc}	6.92^{abc}	7.17^{ab}	7.58^{a}	7.17^{ab}	7.58^{a}	0.11	<0.01	0.14	0.44
Chest circumference	33.4^{e}	34.7^{e}	38.9^{d}	39.6^{d}	44.9^{c}	48.0^{bc}	50.8^{ab}	53.0^{a}	1.07	<0.01	0.22	0.81
Chest depth	8.80^{d}	8.08^{d}	10.2^{d}	15.8^{c}	18.0^{bc}	20.6^{ab}	18.9^{abc}	22.1^{a}	0.86	<0.01	<0.01	0.92

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).

Organ Development

Table 2. Organ development from colostrum to post-weaning in goats (n = 47).

	Diets[1]											
	MC		MM		MMSD		SD			*P*-value		
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Organ weight, g												
Heart	25.2^{c}	29.6^{bc}	33.8^{bc}	32.4^{bc}	40.1^{ab}	46.6^{a}	47.8^{a}	49.2^{a}	1.66	<0.01	0.45	0.62
Liver	92.6^{d}	107^{cd}	122^{cd}	134^{bcd}	142^{bc}	171^{ab}	197^{a}	201^{a}	7.10	<0.01	0.92	0.91
Spleen	6.50^{d}	7.40^{d}	10.6^{cd}	13.9^{bc}	15.2^{abc}	20.4^{a}	19.9^{ab}	18.0^{ab}	0.93	<0.01	<0.01	0.36
Lungs	48.5^{d}	53.6^{d}	64.5^{cd}	68.4^{cd}	85.2^{bc}	112^{ab}	117^{a}	108^{ab}	4.68	<0.01	0.18	0.09
Kidney	25.1^{b}	27.6^{ab}	29.0^{ab}	31.9^{ab}	34.1^{ab}	38.7^{a}	38.3^{a}	37.0^{ab}	1.31	<0.01	0.24	0.64
Head	253^{e}	276de	317de	339^{d}	431^{c}	494^{bc}	523^{b}	617^{a}	19.3	<0.01	0.61	0.92
Hoof	90.8^{e}	106de	122^{cde}	135^{bcd}	135^{bcd}	154^{abc}	159^{ab}	179^{a}	5.07	<0.01	0.56	0.18
Skin	450^{e}	533^{e}	663^{cde}	592de	809^{bcd}	883^{abc}	924^{ab}	1033^{a}	34.7	<0.01	0.69	0.85
Organs of BW, %												
Heart	0.87^{a}	0.86^{a}	0.79^{a}	0.67^{b}	0.60^{bc}	0.59^{bc}	0.54^{cd}	0.48^{d}	0.02	<0.01	0.04	0.43
Liver	3.19^{a}	3.14^{a}	2.78^{a}	2.79^{a}	2.14^{b}	2.18^{b}	2.22^{b}	1.95^{b}	0.08	<0.01	0.08	0.82
Spleen	0.22^{ab}	0.22^{ab}	0.25^{ab}	0.30^{a}	0.23^{ab}	0.26^{ab}	0.23^{ab}	0.18^{b}	0.01	0.20	0.01	0.91
Lungs	1.65^{a}	1.59^{ab}	1.49^{ab}	1.42^{ab}	1.29^{bc}	1.41^{ab}	1.33^{bc}	1.05^{c}	0.04	<0.01	0.88	0.07
Kidney	0.88^{a}	0.80^{ab}	0.67^{bc}	0.66^{bc}	0.52^{cd}	0.49^{d}	0.44^{d}	0.36^{d}	0.03	<0.01	0.17	0.38
Head	8.81^{a}	8.16^{ab}	7.35^{bc}	7.10^{cd}	6.82^{cde}	6.24^{de}	5.92^{de}	6.08^{e}	0.18	<0.01	0.03	0.60
Hoof	3.13^{a}	3.13^{a}	2.85^{a}	2.84^{a}	2.08^{b}	1.93^{b}	1.79^{b}	1.74^{b}	0.10	<0.01	0.13	0.14
Skin	15.3^{a}	15.7^{a}	15.3^{a}	12.3^{b}	12.5^{b}	11.0^{bc}	10.4^{bc}	10.0^{c}	0.39	<0.01	0.15	0.62

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).

Anatomic Development of Digestive Tract

Table 3. The development of forestomach chambers and rumen volume from colostrum to post-weaning in goats (n = 47).

	Diets[1]									P-value		
	MC		MM		MMSD		SD					
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Rumen volume, mL	13.6^{d}	20.0^{d}	54.2^{d}	190^{cd}	376^{bc}	483^{b}	750^{a}	967^{a}	53.5	<0.01	0.03	0.86
Stomach chambers, g												
Rumen	10.6^{d}	12.6^{d}	17.5^{d}	30.4^{d}	67.4^{c}	82.5^{c}	138^{b}	189^{a}	9.35	<0.01	<0.01	0.72
Reticulum	5.50^{c}	4.74^{c}	5.41^{c}	7.04^{c}	16.3^{b}	23.2^{ab}	28.5^{a}	30.3^{a}	1.65	<0.01	0.32	0.01
Omasum	2.47^{d}	2.64^{d}	3.94^{d}	3.82^{d}	6.47^{cd}	11.1^{c}	24.0^{b}	30.1^{a}	1.57	<0.01	<0.01	0.96
Abomasum	28.6^{d}	33.7^{cd}	32.8^{d}	34.1^{cd}	35.4^{bcd}	46.6^{bc}	49.1^{b}	66.9^{a}	2.15	<0.01	0.01	0.33
Complex stomach	47.1^{e}	53.7^{e}	59.6^{e}	75.4^{e}	126^{d}	163^{c}	239^{b}	316^{a}	14.0	<0.01	<0.01	0.96
Percentage of stomach, %												
Rumen	22.5^{c}	24.3^{c}	28.8^{c}	40.9^{b}	53.1^{a}	50.6^{ab}	57.3^{a}	59.6^{a}	2.26	<0.01	<0.01	0.97
Reticulum	11.8^{abc}	8.58^{c}	9.27^{bc}	9.20^{bc}	12.8^{ab}	13.8^{a}	12.0^{abc}	9.60^{bc}	0.45	<0.01	0.06	<0.01
Omasum	5.29^{b}	5.07^{b}	6.78^{b}	5.06^{b}	5.34^{b}	6.75^{b}	9.85^{a}	9.65^{a}	0.38	<0.01	0.02	0.71
Abomasum	60.4^{a}	61.6^{a}	55.1^{a}	44.8^{b}	28.7^{c}	28.8^{c}	20.9^{c}	21.1^{c}	2.53	<0.01	<0.01	0.13
Percentage of BW, %												
Rumen	0.37^{d}	0.38^{d}	0.41^{d}	0.66^{d}	1.06^{c}	1.05^{c}	1.55^{b}	1.85^{a}	0.08	<0.01	0.08	0.90
Reticulum	0.19^{c}	0.14^{c}	0.13^{c}	0.15^{bc}	0.27^{ab}	0.30^{a}	0.32^{a}	0.29^{a}	0.02	<0.01	0.78	0.01
Omasum	0.09^{bc}	0.08^{c}	0.09^{bc}	0.08^{bc}	0.11^{bc}	0.14^{b}	0.27^{a}	0.30^{a}	0.01	<0.01	<0.01	0.48
Abomasum	0.97^{a}	0.96^{a}	0.76^{b}	0.70^{b}	0.56^{b}	0.60^{b}	0.56^{b}	0.66^{b}	0.03	<0.01	<0.01	0.93
Complex stomach	1.61^{c}	1.73^{c}	1.39^{c}	1.58^{c}	1.99^{bc}	2.61^{ab}	2.70^{ab}	3.10^{a}	0.10	<0.01	0.13	0.16

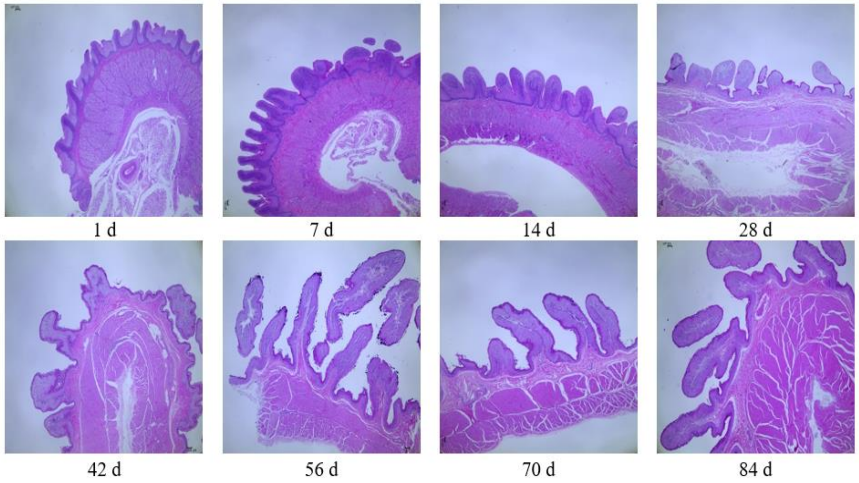
[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).

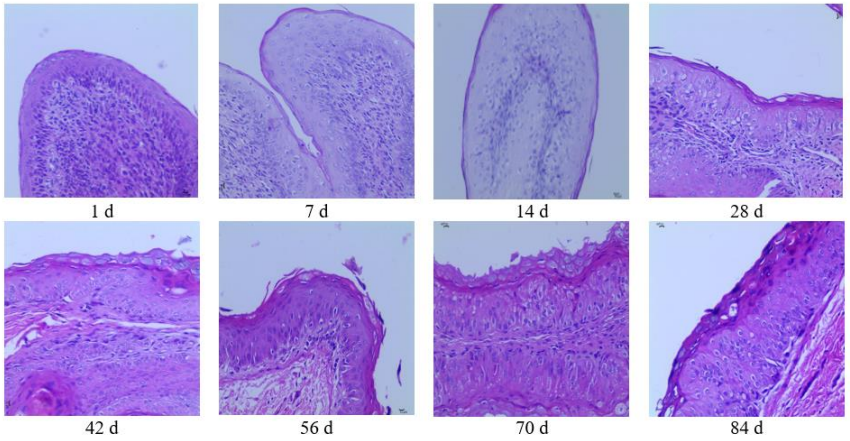
Rumen Development

Table 4. Rumen tissue measurement (microns) from colostrum to post-weaning in goats (n = 47).

	Diets[1]											
	MC		MM		MMSD		SD			*P*-value		
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Papillae height	499^{c,1}	620^{c}	618^{c}	769^{b}	784^{b}	838^{b}	1046^{a}	1162^{a}	16.4	<0.01	0.15	0.03
Papillae width	236^{b}	250^{b}	250^{b}	272^{b}	332^{a}	323^{a}	342^{a}	359^{a}	4.17	<0.01	0.12	0.41
Lamina propria thickness	127^{d}	143^{bcd}	137^{cd}	150^{bcd}	152^{bcd}	182^{bc}	191^{ab}	237^{a}	5.04	<0.01	<0.01	0.11
Muscle layer thickness	683^{c}	732^{c}	730^{c}	734^{c}	781^{bc}	819^{bc}	915^{ab}	1031^{a}	13.5	<0.01	0.01	0.34
Epithelial thickness	49.2^{d}	62.2^{c}	74.9^{b}	73.9^{bc}	72.4^{bc}	71.4^{bc}	74.6^{bc}	90.6^{a}	1.26	<0.01	0.78	<0.01
Stratum corneum thickness	9.20^{c}	9.80^{c}	10.7^{c}	10.2^{c}	21.7^{b}	31.3^{a}	32.3^{a}	39.2^{a}	0.87	<0.01	0.39	<0.01

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).



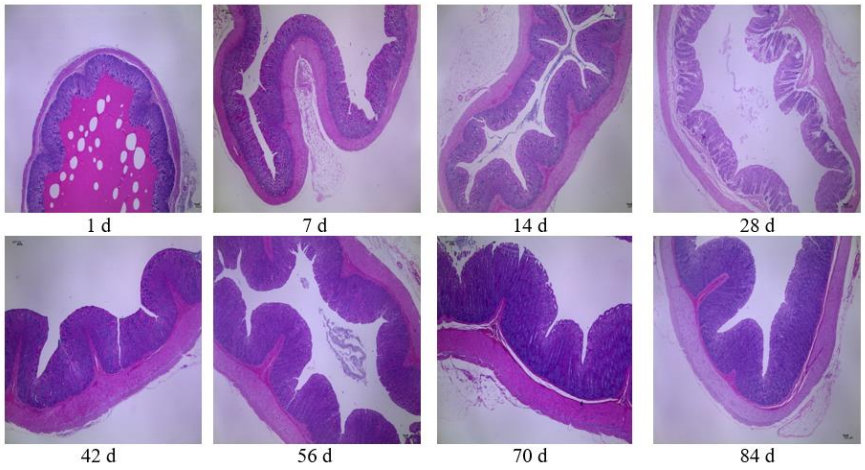


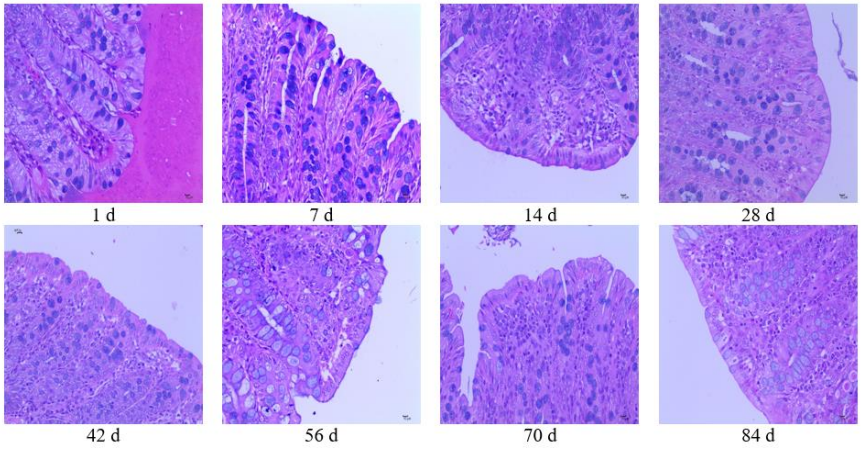
Colon Development

Table 5. Intestine tissue measurement (microns) from colostrum to post-weaning in goats (n = 47).

	Diets[1]											
	MC		MM		MMSD		SD			*P*-value		
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Colon												
Mucosal thickness	378^{d}	378^{d}	411^{d}	536^{c}	539^{c}	570^{bc}	619^{ab}	651^{a}	6.70	<0.01	<0.01	0.20
Muscle layer thickness	179^{c}	239^{b}	240^{b}	243^{ab}	274^{ab}	271^{ab}	273^{ab}	277^{a}	3.79	<0.01	<0.01	0.06
Epithelial thickness	22.9	22.6	24.0	23.7	23.2	24.0	23.5	24.4	0.20	0.07	0.89	0.24

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).



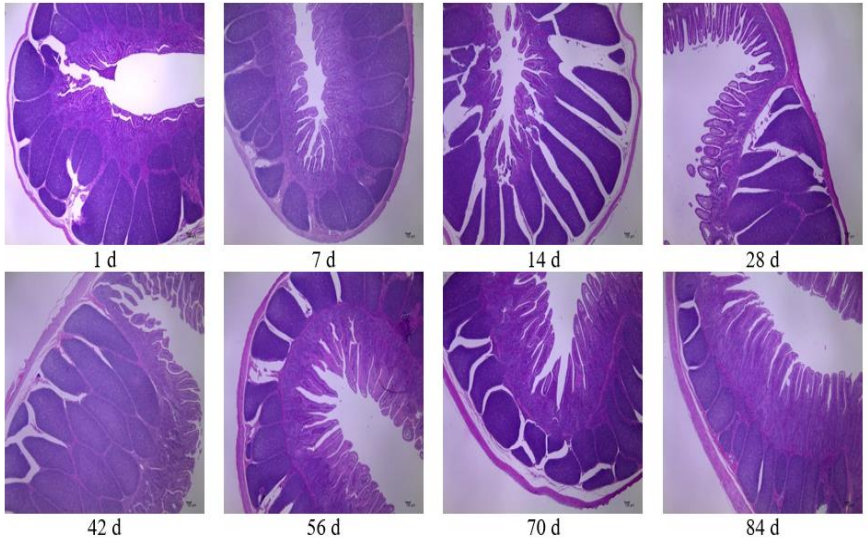


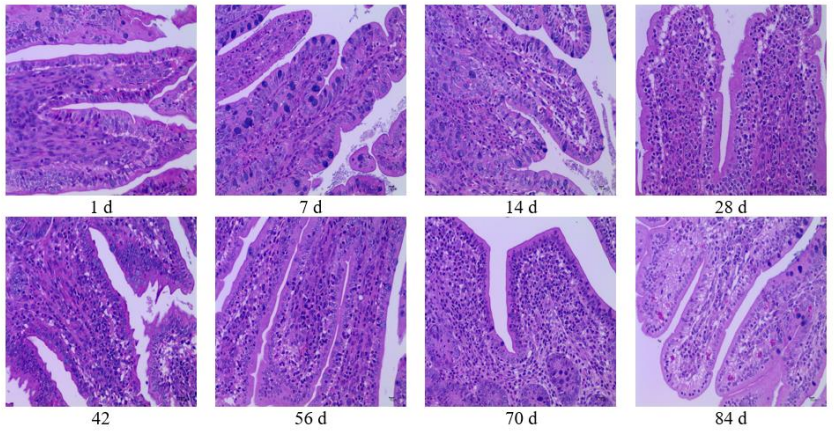
Ileum Development

Table 5. Intestine tissue measurement (microns) from colostrum to post-weaning in goats (n = 47).

	Diets[1]											
	MC		MM		MMSD		SD			*P*-value		
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Ileum												
Villus height	518^{b}	520^{b}	526^{b}	532^{b}	533^{b}	574^{ab}	601^{a}	600^{a}	6.54	<0.01	0.42	0.40
Crypt depth	197^{c}	192^{c}	191^{c}	228^{bc}	243^{ab}	258^{ab}	268^{ab}	275^{a}	4.42	<0.01	0.31	0.43
Muscle layer thickness	103^{c}	131^{bc}	143^{b}	142^{bc}	139^{bc}	148^{b}	163^{b}	227^{a}	4.14	<0.01	0.01	<0.01
Epithelial thickness	19.5^{b}	22.3^{a}	22.2^{a}	22.7^{a}	22.3^{a}	21.9^{a}	21.0^{a}	22.6^{a}	0.27	0.52	0.34	0.01

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).



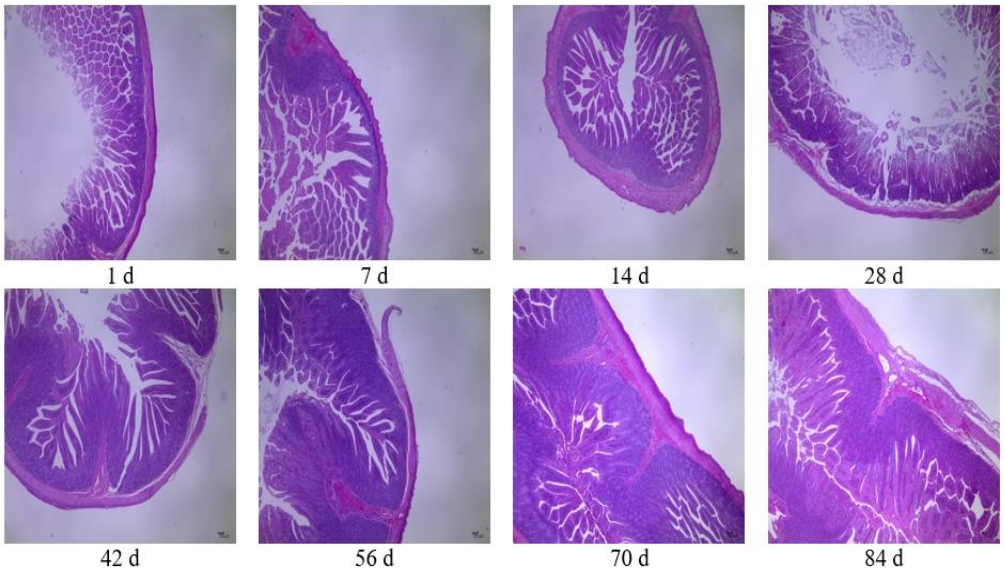


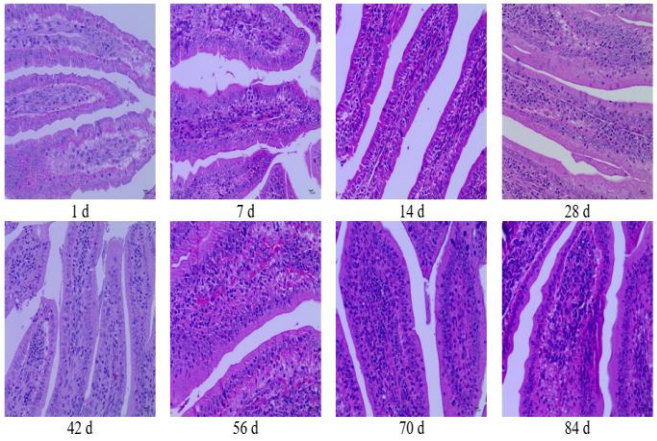
Jejunum Development

Table 5. Intestine tissue measurement (microns) from colostrum to post-weaning in goats (n = 47).

	Diets[1]											
	MC		MM		MMSD		SD			*P*-value		
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Jejunum												
Villus height	633	637	641	643	643	667	667	671	8.06	0.11	0.91	0.85
Crypt depth	213^{c}	217^{c}	230^{c}	290^{b}	317^{ab}	340^{ab}	360^{a}	361^{a}	5.72	<0.01	0.01	0.52
Muscle layer thickness	111^{c}	118^{c}	119^{c}	131^{bc}	147^{ab}	153^{ab}	160^{a}	173^{a}	2.78	<0.01	0.87	0.95
Epithelial thickness	20.6	20.3	21.3	21.8	21.8	21.4	21.1	22.1	0.22	0.12	0.39	0.16

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).



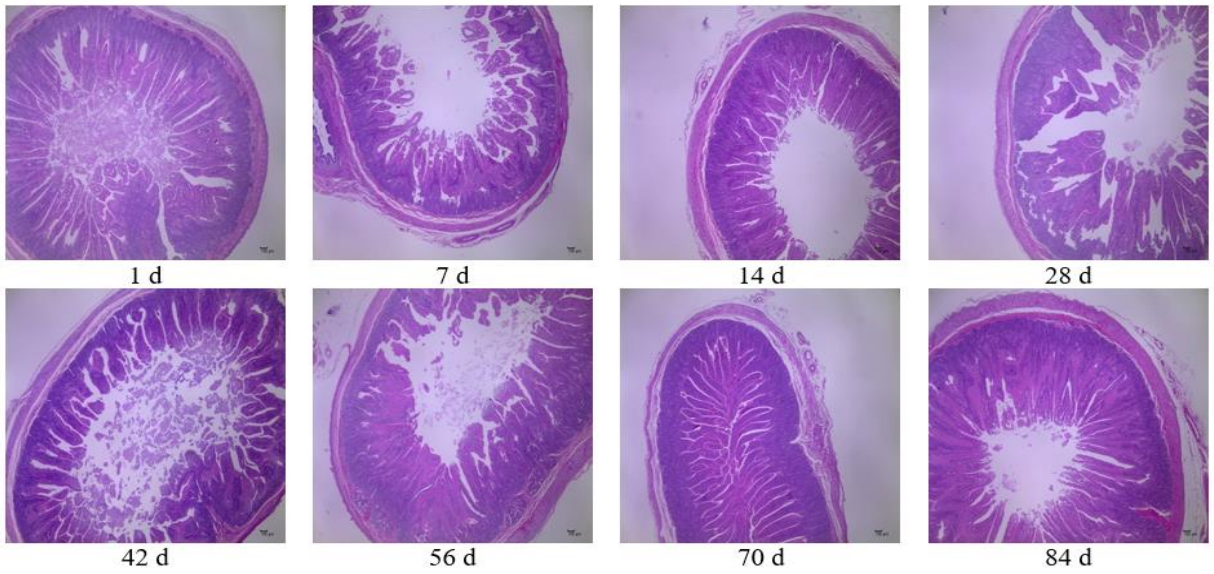


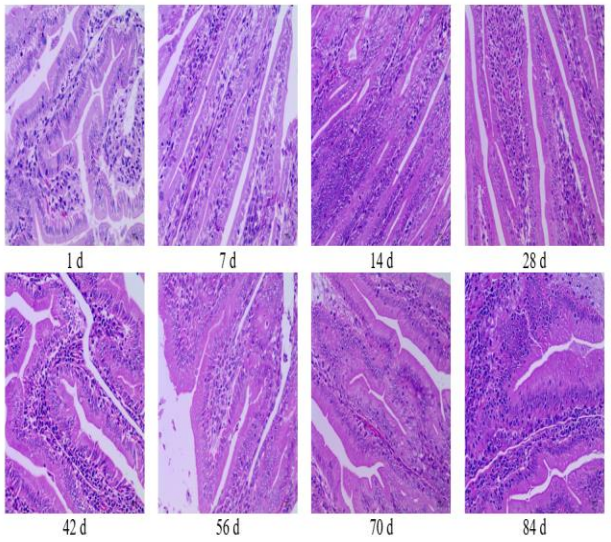
Duodenum Development

Table 5. Intestine tissue measurement (microns) from colostrum to post-weaning in goats (n = 47).

	Diets[1]									*P*-value		
	MC		MM		MMSD		SD					
Items[1]	d1	d7	d14	d28	d42	d56	d70	d84	SEM	Linear	Quadratic	Cubic
Duodenum												
Villus height	652	667	662	683	681	677	703	703	7.15	0.99	0.97	0.94
Crypt depth	216^{c}	267^{b}	288^{ab}	294^{ab}	291^{ab}	306^{a}	313^{a}	317^{a}	3.64	<0.01	<0.01	0.01
Muscle layer thickness	105^{f}	130^{e}	147^{ed}	155^{cd}	155^{bcd}	177^{abc}	178^{ab}	190^{a}	2.43	<0.01	0.03	0.04
Epithelial thickness	22.1^{c}	21.2^{c}	22.3^{c}	24.1^{bc}	27.7^{a}	27.0^{ab}	27.2^{ab}	28.1^{a}	0.32	<0.01	0.04	0.57

[1]Diets: maternal colostrum (MC), maternal milk (MM), maternal milk plus solid diet (MMSD), and solid diet (SD).





Conclusions

The absolute growth of carcass and the dressing percentage was lower at the post- than the pre-weaning stage, indicating weaning stress.

The rumen weight and morphology improved from pre- to post-weaning, and its development was achieved after 2 m of age.

The solid diet phase displayed a crucial role in promoting rumen development.

Adequate nutrition and solid feed before weaning are recommended for the rapid development of the gastrointestinal tract to improve the growth performance of a small ruminant.

Conclusions

- The intestine morphological parameters increased over time, mainly at the earlier stages of milk feeding, indicating the critical role of the small intestine for milk digestion.

- The morphological evolution of the intestine after weaning is associated with rumen development and hence the nutrient availability.

- Beyond feed composition, age was an important factor in increasing the structural development of rumen papillary to endure the shortage of mother milk and the consumption of solid feed to favor the digestive function and performance of the host.

Best regards

Any questions?

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