Effects of Weaning Age on Intestinal Development in Meat Rabbits (Postprint)

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Date: 2017-10-10T00:00:00+00:00

Abstract

This experiment aimed to investigate the effects of weaning age on intestinal development in meat rabbits. The experiment selected 120 litters of newborn meat rabbits, which were randomly divided into 4 treatments with 30 litters per treatment, and weaned at 21, 25, 28, and 35 days of age, respectively, with an experimental period of 56 d. The results showed that: 1) Weaning age had significant or extremely significant effects on the weights of stomach, small intestine, and cecum in meat rabbits at 28 and 35 days of age ($P<0.05$ or $P<0.01$), showing an increasing trend with delayed weaning age, while weaning age had no significant effects on the weights of digestive organs at 49 and 56 days of age and on small intestine length at all ages ($P>0.05$); 2) Weaning age had significant or extremely significant effects on villus height in duodenum (at 28, 35, and 49 days of age), jejunum (at 28, 35, 42, and 49 days of age), and ileum (at 28, 35, 42, and 49 days of age) ($P<0.05$ or $P<0.01$), showing a trend of first increasing then decreasing with delayed weaning age, while having no significant effects on villus height of all intestinal segments at 56 days of age ($P>0.05$). The villus height in meat rabbits required 2-3 weeks to recover after weaning, with the 21-day weaning group showing the slowest recovery and the 35-day weaning group showing the fastest recovery; 3) Weaning age had significant effects on crypt depth in duodenum (at 28 and 35 days of age), jejunum (at 28, 35, and 42 days of age), and ileum (at 35 days of age) ($P<0.05$), showing a decreasing trend with delayed weaning age, while having no significant effects on crypt depth of all intestinal segments at 49 and 56 days of age ($P>0.05$); 4) Weaning age had extremely significant effects on villus height/crypt depth ratio in duodenum, jejunum, and ileum at 28 and 35 days of age ($P<0.01$), showing an increasing trend with delayed weaning age, while having no significant effects on villus height/crypt depth ratio of all intestinal segments at 56 days of age ($P>0.05$). It can be concluded that weaning age had greater effects on intestinal development in meat rabbits before 49 days of age, with the effects diminishing after

49 days of age; early weaning decreased small intestinal mucosal villus height and increased crypt depth; with delayed weaning age, the degree of damage to small intestinal mucosa in meat rabbits caused by weaning was alleviated, and it generally required 2-3 weeks after weaning to recover the small intestinal mucosal structure.

Full Text

Effects of Weaning Age on Intestinal Development of Meat Rabbits

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Abstract

This experiment was conducted to investigate the effects of weaning age on intestinal development in meat rabbits. A total of 120 litters of newborn meat rabbits were selected and randomly divided into four treatment groups (30 litters per group), which were weaned at 21, 25, 28, and 35 days of age, respectively. The experimental period lasted 56 days. The results showed that: (1) Weaning age had significant or highly significant effects on the weights of stomach, small intestine, and cecum at 28 and 35 days of age ($P < 0.05$ or $P < 0.01$), with a trend of increase as weaning age was delayed. However, weaning age had no significant effect on the weight of digestive organs at 49 and 56 days of age, nor on small intestine length at any age ($P > 0.05$). (2) Weaning age had significant or highly significant effects on villus height in the duodenum (at 28, 35, and 49 days), jejunum (at 28, 35, 42, and 49 days), and ileum (at 28, 35, 42, and 49 days) ($P < 0.05$ or $P < 0.01$), showing a trend of initial increase followed by decrease with delayed weaning age. No significant effect was observed on villus height in any intestinal segment at 56 days of age ($P > 0.05$). Villus height required 2–3 weeks to recover after weaning, with the 21-day weaning group showing the slowest recovery and the 35-day weaning group the fastest. (3) Weaning age significantly affected crypt depth in the duodenum (at 28 and 35 days), jejunum (at 28, 35, and 42 days), and ileum (at 35 days) ($P < 0.05$), with a decreasing trend as weaning age was delayed. No significant effects were found on crypt depth in any intestinal segment at 49 and 56 days of age ($P > 0.05$). (4) Weaning age had highly significant effects on the villus height/crypt depth (V/C) ratio in the duodenum, jejunum, and ileum at 28 and 35 days of age ($P < 0.01$), with an increasing trend as weaning age was delayed, but no significant effect at 56 days of age ($P > 0.05$). In conclusion, weaning age substantially affected intestinal development before 49 days of age but had minimal influence thereafter. Early weaning reduced small intestinal mucosal villus height and increased crypt depth. As weaning age was delayed, the degree of small intestinal mucosal damage decreased, and the

mucosal structure generally required 2–3 weeks to recover after weaning.

Keywords: weaning age; meat rabbits; intestinal development

Introduction

Modern intensive rabbit production demands full exploitation of the reproductive potential of does, including shortened kindling intervals and increased annual litter numbers. Early weaning of kits is an important measure to achieve this reproductive efficiency. However, weaning poses a significant stress to young rabbits. Due to their immature gastrointestinal development, kits are prone to digestive diseases that can cause diarrhea and death. Therefore, understanding the effects of different weaning ages on gastrointestinal development and function is crucial for guiding scientific early weaning practices in meat rabbits.

In 1978, Chen et al. and Rao et al. investigated the effects of weaning age (28, 42, and 56 days) on meat rabbit production and found no effects on body weight, feed efficiency, or carcass quality, though mortality decreased with delayed weaning. They concluded that 28-day weaning was most economical. De Bias et al. reported that weaning age (25 and 35 days) significantly or highly significantly affected dry matter and digestible energy intake and body weight at 49 and 63 days, but not average daily gain or weight at 77 days, suggesting 25-day weaning was preferable. Ferguson et al. found that rabbits weaned at 14 days and artificially fed from 14–21 days had 0.2 kg lower body weight at 70 days compared to those weaned at 28 days, though litter size and feed intake did not differ significantly, indicating artificial feeding technology was feasible.

Few studies have examined differences in gastrointestinal development of commercial meat rabbits at various times under different weaning age conditions. Therefore, in-depth research on the effects of weaning age on gastrointestinal morphology and function is needed to provide theoretical reference for early weaning technology. This study aimed to investigate the effects of different weaning ages on digestive tract morphological development and function, providing scientific basis for determining optimal weaning age and developing feed formulations.

Materials and Methods

1.1 Experimental Design

A total of 120 litters of newborn New Zealand rabbits were randomly divided into four groups with no significant differences in litter size or weight among groups (30 litters per group). The groups were weaned at 21, 25, 28, and 35 days of age, designated as W21, W25, W28, and W35, respectively. The experimental period was 56 days.

1.2 Management

Experimental does were managed by dedicated personnel with consistent feeding practices. On the day of kindling, cross-fostering was performed to ensure each doe nursed eight kits. During lactation, does and kits were housed separately, with kits allowed to nurse once daily at 09:00 for approximately 10 minutes. Kits began supplemental feeding at 16 days of age with ad libitum access. All rabbits were ear-tagged at 35 days of age and group-housed by size and sex, with three kits per 60 cm × 60 cm cage. At 42 days of age, rabbits were vaccinated with 1.5 mL of rabbit hemorrhagic disease-pasteurellosis combined vaccine per animal. Kits were fed a meat rabbit diet until the end of the experiment. Diet composition and nutrient levels are presented in Table 1 . All rabbits had automatic access to water, and the rabbitry was cleaned daily.

Table 1 Diet composition and nutrient levels (air-dry basis) %

Item	Content
Ingredients	
Alfalfa meal	
Soybean meal	
Corn	
Rice bran fresh	
Rapeseed meal	
Wheat bran	
L-Lys	
NaCl	
CaHPO4	
Limestone	
Premix[1])	
Total	
Nutrient levels[2])	
ME/(MJ/kg)	
CF	
CP	
Ca	
TP	

[1]) The premix provided the following per kg of diet: Fe 100 mg, Cu 20 mg, Zn 90 mg, Mn 30 mg, Mg 150 mg, VA 4,000 IU, VD 1,000 IU, VE 50 mg, choline 1 mg.
[2]) DE was a calculated value, while other nutrient levels were measured values.

1.3 Measurements and Methods

From each group, six rabbits with body weight close to the group average (half male and half female) were selected at 21, 28, 35, 42, and 56 days of age. After

1 hour of feeding on the sampling day, rabbits were slaughtered by exsanguination via jugular vein. The abdominal cavity was immediately opened, and the pyloric and ileocecal valves were ligated. The digestive tract was removed and carefully separated according to anatomical characteristics, with the small intestine divided into duodenum, jejunum, and ileum.

1.3.1 Digestive Organ Weight and Length Measurement Small intestinal loops were carefully separated from the mesentery, and natural length was measured with a soft ruler as small intestine length. The stomach, small intestine, and cecum were washed free of contents, blotted on filter paper to remove excess water, and weighed to obtain digestive organ weights. Sample portions were estimated and included in total weight.

1.3.2 Small Intestinal Mucosal Morphology Measurement A 2-cm segment from the middle portion of the duodenum, jejunum, and ileum was excised, rinsed with physiological saline, and immediately fixed in 10% formalin solution. Paraffin sections were prepared using conventional methods and stained with hematoxylin-eosin. Villus height and crypt depth were measured according to Sun et al., and the villus height/crypt depth (V/C) ratio was calculated. Villus height was measured from the villus tip to the crypt opening, and crypt depth was measured from the invagination between adjacent villi.

1.4 Statistical Analysis

Experimental data were processed using Excel 2007 software and analyzed by one-way ANOVA using SPSS 17.0 statistical software. Duncan' s multiple range test was used for pairwise comparisons, with $P < 0.05$ as the significance threshold. Results are expressed as "mean ± standard deviation."

Results

2.1 Effects of Weaning Age on Digestive Organ Weight and Small Intestine Length

As shown in Table 2 , the weights of stomach, small intestine, and cecum generally increased with delayed weaning age. Weaning age significantly affected stomach weight at 28, 35, and 42 days of age ($P < 0.05$) but not at 21, 49, or 56 days ($P > 0.05$). Weaning age highly significantly affected small intestine weight at 28 days ($P < 0.01$) and significantly at 35 days ($P < 0.05$), with no significant effects at 42, 49, or 56 days ($P > 0.05$). Significant differences in cecum weight were observed at 28 and 42 days ($P < 0.05$) and highly significant differences at 35 days ($P < 0.01$). At 28, 35, and 42 days, the early-weaned W21 group had lower cecum weights than other groups, but differences gradually diminished with delayed weaning age, with no significant differences among groups after 49 days ($P > 0.05$). Weaning age had no significant effect on small intestine length ($P > 0.05$).

Table 2 Effects of weaning age on digestive organ weight and small intestine length of meat rabbits

In the same row, values with no letter or the same letter superscripts indicate no significant difference ($P > 0.05$), different lowercase letters indicate significant difference ($P < 0.05$), and different capital letters indicate highly significant difference ($P < 0.01$). The same applies below.

2.2 Effects of Weaning Age on Small Intestinal Mucosal Villus Height

As shown in Table 3 , villus height generally increased initially then decreased with delayed weaning age. Weaning age significantly or highly significantly affected duodenal villus height at 28, 35, and 49 days ($P < 0.05$ or $P < 0.01$) but not at 42 or 56 days ($P > 0.05$). Weaning age significantly or highly significantly affected jejunal and ileal villus height at 28, 35, 42, and 49 days ($P < 0.05$ or $P < 0.01$) but not at 56 days ($P > 0.05$). These results indicate that the effect of weaning age on villus height gradually decreased with increasing age, with small intestinal villi requiring 2–3 weeks to recover after weaning.

Table 3 Effects of weaning age on intestinal mucosal villus height of meat rabbits (m)

2.3 Effects of Weaning Age on Small Intestinal Mucosal Crypt Depth

As shown in Table 4 , crypt depth generally decreased with delayed weaning age. Weaning age significantly affected duodenal crypt depth at 28 and 35 days ($P < 0.05$) but not at 42, 49, or 56 days ($P > 0.05$). Weaning age significantly affected jejunal crypt depth at 28, 35, and 42 days ($P < 0.05$) but not at 49 or 56 days ($P > 0.05$). Weaning age significantly affected ileal crypt depth at 35 days ($P < 0.05$) but not at 28, 42, 49, or 56 days ($P > 0.05$). These findings indicate that weaning age had greater effects on crypt depth in the anterior small intestine than in the posterior segments, with crypt depth recovering within 1–2 weeks after weaning—shorter than the recovery time for villus height.

Table 4 Effects of weaning age on intestinal mucosal crypt depth of meat rabbits (m)

2.4 Effects of Weaning Age on Small Intestinal Mucosal V/C Ratio

As shown in Table 5 , the V/C ratio generally increased with delayed weaning age. Weaning age highly significantly affected duodenal V/C ratio at 28 and 35 days ($P < 0.01$) and significantly at 49 days ($P < 0.05$), with no significant effects at 42 or 56 days ($P > 0.05$). Weaning age highly significantly affected jejunal V/C ratio at 28, 35, and 42 days ($P < 0.01$) but not at 49 or 56 days ($P > 0.05$). Weaning age highly significantly affected ileal V/C ratio at 28 and 35 days ($P < 0.01$) but not at 42, 49, or 56 days ($P > 0.05$). These results demonstrate that the effect of weaning on the V/C ratio was concentrated within 1–2 weeks after weaning, with earlier weaning having greater impact.

Table 5 Effects of weaning age on intestinal mucosal V/C ratio of meat rabbits

Discussion

3.1 Effects of Weaning Age on Digestive Organ Weight and Small Intestine Length

This study found that weaning age had significant or highly significant effects on stomach, small intestine, and cecum weights at 28 and 35 days of age. Earlier weaning resulted in smaller digestive organs at the same age, while later weaning produced larger organs. No significant differences in digestive organ weights were observed among different weaning age groups after 49 days, indicating compensatory development in meat rabbits. Xiccato et al. reported that 18-day-weaned kits had significantly lower body weight than 30-day-weaned kits at 35 days, but the difference diminished by 50 days, corroborating our findings of compensatory growth and suggesting that weaning age does not significantly affect slaughter weight. This study found no significant effect of weaning age on small intestine length, possibly related to regional growth patterns where small intestine length develops prior to mucosal structure. These results demonstrate compensatory growth in rabbit intestinal development, supporting the feasibility of early weaning.

3.2 Effects of Weaning Age on Small Intestinal Mucosal Development

In this experiment, weaning age substantially affected villus height, crypt depth, and V/C ratio at 28, 35, and 42 days of age. Earlier weaning resulted in lower villus height and deeper crypts. Later weaning also reduced villus height and increased crypt depth, but to a lesser extent. Gu et al. studied intestinal development patterns in piglets weaned at different ages and found that earlier weaning caused more severe intestinal mucosal damage requiring longer recovery time, with villus height reaching its lowest point 8–12 days post-weaning before recovering rapidly. Similarities exist between piglet and kit intestinal mucosal development after weaning. Bivolarski et al. also reported that while average villus height did not differ significantly between early- and normal-weaned rabbits throughout the growth period, significant differences in villus height and crypt depth were observed on day 1 post-weaning. This study also found that weaning age had no significant effect on intestinal mucosal structure at 56 days, indicating that intestinal mucosa recovered within 2–3 weeks after weaning, though the early-weaned group required longer recovery time.

Conclusions

1. Weaning age substantially affected intestinal development before 49 days of age but had minimal influence after 49 days.

2. Early weaning reduced small intestinal mucosal villus height and increased crypt depth.

3. As weaning age was delayed, the degree of small intestinal mucosal damage decreased, and the mucosal structure generally required 2–3 weeks to recover after weaning.

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Note: Figure translations are in progress. See original paper for figures.