Effects of Sustained-Release Calcium Hydroxide and Sustained-Release Hydrochloric Acid on Nutrient Digestion and Absorption in Rabbits (Postprint)

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Abstract

This experiment utilized rabbits weighing (2.0$±$0.5) kg as experimental animals, and employed sustained-release calcium hydroxide and sustained-release hydrochloric acid to modulate digestion and absorption, thereby determining their effects on nutrient digestion and absorption. Results showed that sustained-release calcium hydroxide enhanced nutrient digestion and absorption, particularly for calcium and crude protein, with digestibility increasing from 41.0% and 65.2% to 89.8% and 93.8%, respectively; sustained-release hydrochloric acid had adverse effects on nutrient digestion and absorption, especially for calcium and crude protein, with digestibility decreasing from 55.5% and 84.9% to 28.4% and 68.7%, respectively; furthermore, the promoting effect of sustained-release calcium hydroxide on digestion and absorption could be maintained for 2–4 days. It can thus be concluded that sustained-release calcium hydroxide facilitates calcium and protein digestion and absorption, whereas fat digestion and absorption remain efficient under all conditions, making increased fat intake prone to cause nutritional excess. However, administration of sustained-release hydrochloric acid reduces the effectiveness of nutrient digestion and absorption.

Full Text

Effects of Sustained-Release Calcium Hydroxide and Sustained-Release Hydrochloric Acid on Nutrient Digestion and Absorption in Rabbits

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Abstract

This study investigated the effects of sustained-release calcium hydroxide and sustained-release hydrochloric acid on nutrient digestion and absorption in rabbits weighing (2.0$±$0.5) kg. The results demonstrated that sustained-release calcium hydroxide significantly enhanced the digestion and absorption of nutrients, particularly calcium and crude protein, with digestibility increasing from 41.0% to 89.8% for calcium and from 65.2% to 93.8% for crude protein. Conversely, sustained-release hydrochloric acid adversely affected nutrient digestion and absorption, especially for calcium and crude protein, with digestibility decreasing from 55.5% to 28.4% for calcium and from 84.9% to 68.7% for crude protein. Furthermore, the pro-digestive effects of sustained-release calcium hydroxide persisted for 2–4 days. These findings indicate that sustained-release calcium hydroxide promotes calcium and protein digestion and absorption, while fat digestion remains highly efficient regardless of conditions, suggesting that increased fat intake readily leads to nutritional excess. However, administration of sustained-release hydrochloric acid reduces nutrient digestion and absorption efficiency.

Keywords: sustained-release calcium hydroxide; sustained-release hydrochloric acid; nutrients; digestion and absorption; influence; rabbits

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Introduction

Nutrient digestion and absorption form the foundation for physiological functional regulation in organisms. In modern society, food abundance and diversity, coupled with increased life and work stress, have created an imbalance in human nutrition: excessive intake of energy-supplying substances (primarily glucose and fat) on one hand, and insufficient intake of minerals and protein on the other. This nutritional imbalance has led to metabolic disorders and calcium loss, seriously compromising health. Extensive research has been conducted on nutritional balance, including studies on the effects of berberine on digestion and metabolism in meat rabbits and glucose-lipid metabolism in rats, as well as the impact of sodium bicarbonate supplementation in chicken or cattle feed on nutrient metabolism. A patented drug combination for autonomic nerve regulation, comprising sustained-release calcium hydroxide and sustained-release hydrochloric acid, has been disclosed in the literature. This study employs rabbits as model animals to investigate the effects of sustained-release calcium hydroxide and sustained-release hydrochloric acid on nutrient digestion and absorption, providing novel insights for human nutritional balance regulation.

1. Materials and Methods

1.1 Experimental Materials

Medicinal montmorillonite (Inner Mongolia Runlong Chemical Co., Ltd., montmorillonite content 95%-98%, heavy metal content $ $10 mg/kg, arsenic content $ $2 mg/kg); #3 hollow enteric-coated capsules (Huangshan Capsule Co., Ltd.); analytically pure grade potassium sulfate, hydrochloric acid, calcium hydroxide, stearic acid, boric acid, concentrated sulfuric acid, copper sulfate, sodium hydroxide, potassium hydroxide, petroleum ether, and 95% ethanol.

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1.2 Preparation of Sustained-Release Capsules

1.2.1 Sustained-Release Calcium Hydroxide Enteric Capsules Following methods described in references [9-10], medicinal montmorillonite was acid-activated to obtain wet acidic montmorillonite. Twenty grams (dry basis) of acidic montmorillonite was added to 500 mL deionized water, followed by the addition of 16.00 g of lime milk containing 30% calcium hydroxide at 75°C. The mixture was loaded for 4 hours, then slowly treated with stearic acid for surface modification, and finally filtered, dried, and pulverized to obtain sustained-release calcium hydroxide powder, which was filled into #3 hollow enteric-coated capsules.

1.2.2 Sustained-Release Hydrochloric Acid Enteric Capsules Twenty grams (dry basis) of acidic montmorillonite was added to 500 mL deionized water, followed by the addition of 0.60 g of lime milk containing 30% calcium hydroxide at 75°C. The mixture was loaded for 5 minutes, then slowly treated with stearic acid for surface modification, and finally filtered, dried, and pulverized to obtain sustained-release hydrochloric acid powder, which was filled into #3 hollow enteric-coated capsules.

1.3 Experimental Diets

Adult rabbits (Chinese white rabbits) were purchased from the Animal Breeding Base of Guangxi University. Experimental diets were purchased in two batches from Guangnan Nanning Guanbo Feed Co., Ltd. Table 1 presents the nutrient level analysis of the experimental diets, with crude ash, crude fat, and crude protein content measured directly, while crude starch content was calculated. The crude ash contained primarily sodium chloride in addition to measured calcium. The first batch of diet was used for the sustained-release calcium hydroxide digestion trial, and the second batch for the sustained-release hydrochloric acid digestion trial.

1.4 Experimental Methods

1.4.1 Effects of Sustained-Release Calcium Hydroxide on Nutrient Digestion and Absorption Sixteen rabbits weighing (2.0$±$0.5) kg were selected (half male, half female) and randomly divided into 4 groups (n=4 each): blank control, low-dose sustained-release calcium hydroxide, medium-dose, and high-dose groups. In addition to free feeding and drinking, the treatment groups received daily gavage of sustained-release calcium hydroxide at doses of 2.5, 5.0, and 10.0 mg/kg body weight, respectively.

The trial was conducted in August 2015, with average temperature 33°C and average relative humidity 84%. Rabbits were fed the first batch of diet, with a 3-day adaptation period followed by a 5-day trial period. Each rabbit was housed individually and fed twice daily (morning and evening). The drug was administered once daily during the trial period. Feces were collected continuously for 5 days, dried at 70°C for 3 hours, pulverized and sieved, then analyzed for dry matter, crude fat, crude protein, and crude ash digestibility. Body weight was measured before and after the trial.

1.4.2 Cyclic Changes in Nutrient Digestion and Absorption After Discontinuation of Sustained-Release Calcium Hydroxide After discontinuing sustained-release calcium hydroxide administration, feces were collected daily, dried at 70°C for 3 hours, pulverized and sieved, and dry matter digestibility was measured. When dry matter digestibility decreased to pre-administration levels, another dose of sustained-release calcium hydroxide was administered until digestibility returned to post-administration levels for the second time.

1.4.3 Effects of Sustained-Release Hydrochloric Acid on Nutrient Digestion and Absorption Eight rabbits weighing (2.5$±$0.5) kg were selected (half male, half female) and randomly divided into 2 groups (n=4 each): blank control and sustained-release hydrochloric acid groups. The control group received free feeding and drinking, while the treatment group received daily gavage of sustained-release hydrochloric acid at 25 mg/kg body weight in addition to free feeding and drinking.

The trial was conducted in October 2015, with average temperature 28°C and average relative humidity 79%. Rabbits were fed the second batch of diet, with a 3-day adaptation period followed by a 7-day trial period. Each rabbit was housed individually and fed twice daily. The drug was administered once daily during the trial period. Feces were collected continuously for 5 days, dried at 70°C for 3 hours, pulverized and sieved, and dry matter digestibility was measured. Body weight was measured before and after the trial, and feed intake was recorded.

1.5 Index Determination

Diet and fecal samples were analyzed for dry matter (DM), crude protein (CP), crude fat (EE), and crude ash content according to methods in *Feed Analysis and Feed Quality Detection Technology* [11]. Calcium content was determined by inductively coupled plasma (ICP) spectroscopy. Crude starch content was estimated by subtracting crude ash, crude fat, and crude protein from total diet. Nutrient absorption was approximated as nutrient intake minus nutrient excretion.

Nutrient digestibility was calculated as follows:
Dry matter digestibility (%) = [(DM intake -DM excretion) / DM intake] × 100
Crude protein digestibility (%) = [(CP intake -CP excretion) / CP intake] × 100
Crude fat digestibility (%) = [(EE intake -EE excretion) / EE intake] × 100
Crude starch digestibility (%) = [(Crude starch intake -Crude starch excretion) / Crude starch intake] × 100

1.6 Statistical Analysis

Data were analyzed using SPSS 17.0 statistical software. Results are expressed as mean ± standard deviation. Significant differences were analyzed by LSD multiple comparison tests, with $P < 0.01$ considered extremely significant, $P < 0.05$ significant, and $P > 0.05$ not significant.

2. Results

2.1 Effects of Sustained-Release Calcium Hydroxide on Digestion and Absorption

As shown in Table 2 , the medium- and high-dose sustained-release calcium hydroxide groups exhibited significantly lower average daily feed intake compared to the blank control group ($P < 0.05$), while the low-dose group showed no significant difference ($P > 0.05$). Calcium and crude protein absorption in the low-, medium-, and high-dose groups were significantly higher than in the control group ($P < 0.05$), whereas dry matter, crude fat, and crude starch absorption showed no significant differences ($P > 0.05$). Dry matter, crude ash, calcium, crude fat, crude protein, and crude starch digestibility were all extremely significantly higher in the treatment groups than in the control group ($P < 0.01$). No significant differences in body weight change were observed among groups ($P > 0.05$).

Figure 1 [Figure 1: see original paper] shows the dry matter digestibility in the medium-dose group during cyclic administration. Day 1 represents the first day after discontinuing sustained-release calcium hydroxide. By day 6 post-discontinuation, dry matter digestivity had decreased to pre-administration levels. A subsequent dose on day 7 restored digestibility to post-administration

levels by day 10, indicating that each administration maintained high digestibility for 3–4 days, though the effect declined relatively quickly.

2.2 Effects of Sustained-Release Hydrochloric Acid on Digestion and Absorption

As shown in Table 3 , the sustained-release hydrochloric acid group exhibited extremely significantly lower average daily feed intake compared to the blank control group ($P < 0.01$). Dry matter, crude ash, calcium, crude fat, crude protein, and crude starch absorption were all extremely significantly lower in the treatment group ($P < 0.01$). Dry matter, crude ash, crude fat, and crude protein digestibility were extremely significantly lower in the treatment group ($P < 0.01$), while calcium and crude starch digestibility were significantly lower ($P < 0.05$). The treatment group showed decreased body weight, while the control group gained weight, with significant differences between groups ($P < 0.05$).

3. Discussion

3.1 Effects of Sustained-Release Calcium Hydroxide on Nutrient Digestion and Absorption

ZHUGE Liuying et al. [12] investigated the anti-inebriation effects of sustained-release calcium hydroxide in rabbits and found that it accelerated alcohol metabolism and restored appetite more quickly. The present study demonstrates that sustained-release calcium hydroxide enhances digestion and absorption, likely by augmenting parasympathetic nervous system activity. Current research on digestion enhancement primarily focuses on increasing gastric juice secretion and pepsin output, such as studies on Jianweishu chewable tablets [13] and Zhangbao [14]. This study approaches the issue from the perspective of autonomic nerve regulation, modulating nutrient digestion and absorption through autonomic nervous system control.

Neurophysiological research indicates that the parasympathetic nervous system increases digestive juice secretion and promotes gastrointestinal motility [15], exerting predominantly facilitative effects on digestion and absorption. Reduced parasympathetic activity has been identified in various gastrointestinal motility disorders, including functional dyspepsia [16] and irritable bowel syndrome [17], suggesting that treatment of these conditions should target parasympathetic hypofunction.

Data in Table 2 show that calcium and crude protein absorption and digestibility increased progressively with sustained-release calcium hydroxide dosage. Observationally, rabbits exhibited improved mental status after administration, likely resulting from enhanced calcium and protein absorption. Crude fat and crude starch absorption were unaffected by dosage, though their digestibility increased with dosage up to the medium dose, after which it plateaued. This pattern mirrors the changes in feed intake, attributable to individual housing maintaining

relatively constant daily nutrient consumption and the absence of significant weight changes, resulting in stable starch and fat utilization. Reduced feed intake occurred because sustained-release calcium hydroxide improved nutrient digestibility, and since all groups maintained normal activity with similar energy expenditure, less energy supplementation was required compared to the control group. Figure 1 demonstrates that daily administration is unnecessary; dosing every 2–4 days effectively improves digestion and absorption. This suggests the mechanism involves parasympathetic enhancement rather than increased intestinal enzyme activity, as the short intestinal residence time of sustained-release calcium hydroxide cannot sustain effects for 2–4 days.

3.2 Effects of Sustained-Release Hydrochloric Acid on Nutrient Digestion and Absorption

Sustained-release hydrochloric acid reduced digestion and absorption, likely by enhancing sympathetic nervous system activity. Sympathetic activation reduces digestive juice secretion, slows gastrointestinal motility, decreases esophageal sphincter tone, increases gastric fundus tension, reduces antral contraction amplitude, delays gastric emptying, and slows small intestine transit [18].

Data in Table 3 show that calcium and crude protein absorption and digestibility decreased markedly after sustained-release hydrochloric acid administration, contrasting with parasympathetic enhancement effects. The reduced crude fat and crude starch absorption and digestibility primarily resulted from decreased feed intake and slight weight loss, possibly reflecting maladaptation to sympathetic enhancement during autumn.

Comparison of control groups between Table 2 (summer) and Table 3 (autumn) reveals higher feed intake and nutrient absorption in autumn, attributable to high summer temperatures enhancing sympathetic activity [19]. Data from both tables indicate that fat digestion and absorption remain highly efficient regardless of season or autonomic state, suggesting that increased fat intake readily causes nutritional excess. However, season and autonomic state substantially affect calcium absorption, with high temperatures and sympathetic activation severely inhibiting calcium absorption.

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