Fermented Rapeseed Meal Mitigates Intestinal and Hepatic Injuries via Gut Microbiota Modulation and Autophagy Activation in Koi carp (Cyprinus carpio)

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Abstract:

This study aimed to evaluate whether fermentation of rapeseed meal (FRSM) can mitigate the adverse effects of rapeseed meal (RSM) on growth performance, intestinal health, and liver function in koi carp (Cyprinus carpio). A total of 81 koi carp were randomly assigned to three dietary groups: a control group receiving a soybean meal (SBM) diet, a group fed an unfermented rapeseed meal (RSM) diet, and a group fed a fermented rapeseed meal (FRSM) diet. Growth performance, serum biochemical parameters, tissue histology, gut microbiota composition, and transcriptomic profiles were assessed at the end of the feeding trial. The results showed that weight gain, weight gain rate, and specific growth rate were significantly lower in the RSM and FRSM groups compared to the SBM group ($P < 0.05$). Serum antioxidant enzyme activities, including SOD, CAT, and GSH-PX, were significantly decreased, while MDA levels and AST activity were significantly increased in the RSM and FRSM groups ($P < 0.001$). Histological analysis indicated intact intestinal villus structures across all groups, however, crypt depth was significantly reduced in the FRSM group ($P = 0.019$). Scanning electron microscopy revealed a higher microvilli density in the SBM group compared to both the RSM and FRSM groups. Severe hepatic pathological changes were observed in the RSM group, whereas hepatic damage was notably alleviated in the FRSM group. LEfSe analysis identified the Ruminococcus torques group as a key biomarker in the FRSM group. RSM induced significant transcriptomic alterations in the intestine and liver, characterized by increased oxidative stress, metabolic dysfunction, and activation of inflammatory pathways. FRSM transformed these responses by enhancing autophagy, lipid metabolism, and cellular repair mechanisms, indicating a protective and regenerative effect. In conclusion, dietary supplementation with FRSM may alleviate intestinal and hepatic injuries induced by high-level RSM inclusion, potentially through gut-liver axis modulation, enrichment of Ruminococcus torques group, and activation of autophagy-related pathways.

Keywords:
fermentation; morphology; gut microbiota; Ruminococcus torques group; autophagy.

Results

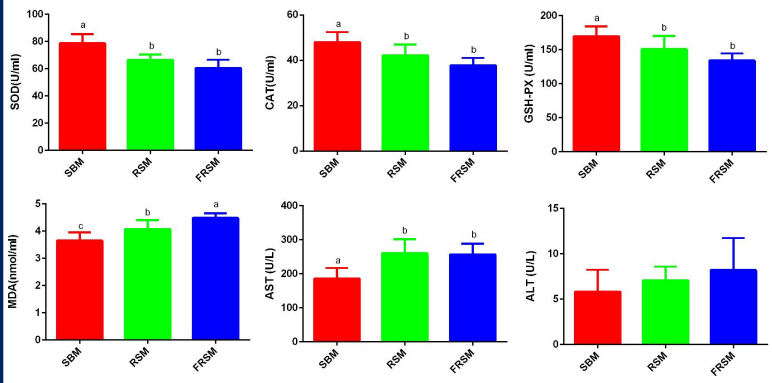

Fig. 1. Serum parameters

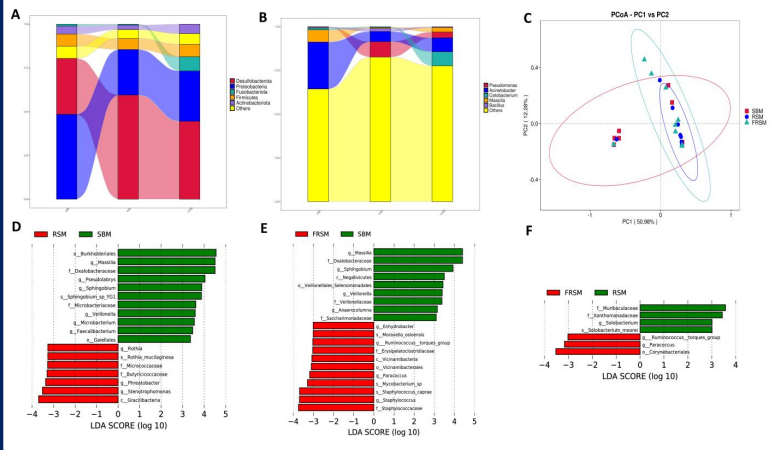

Fig. 2. Gut microbiota composition and diversity among the SBM, RSM, and FRSM groups.

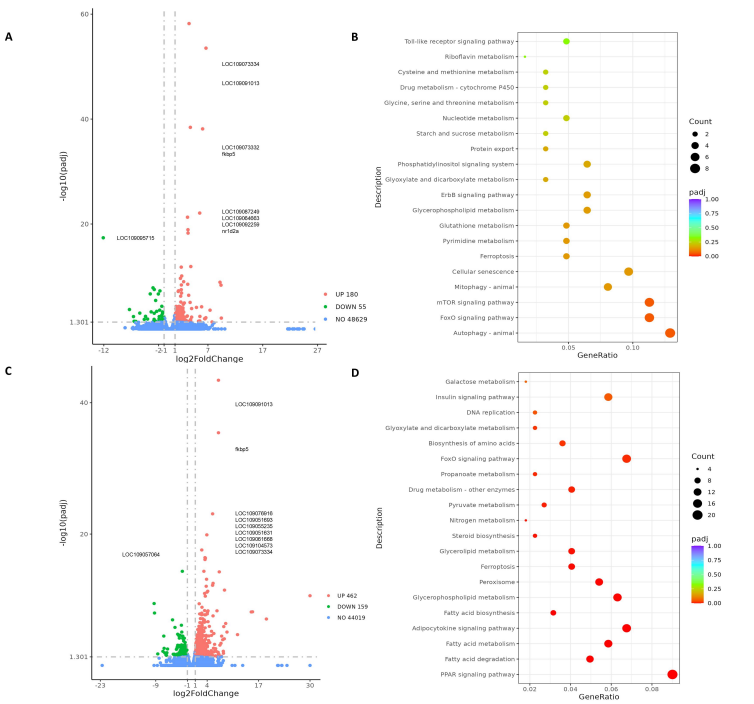

Fig. 3. DEGs and KEGG pathway enrichment between the FRSM and RSM groups.