Improvement of Feeding Value of Quinoa Stalk with White Rot Fungi Treatment

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Key words: white rot fungi; quinoa stalk; acid detergent lignin

Abstract

Two trials were conducted to evaluate the effect of white rot fungi treatment on feeding value of quinoa stalk. In trial 1, quinoa stalk was inoculated with *Pleurotus osteratus* (PO) or *Pleurotus citrinopileatus* (PC) at 25 °C for 90 days, and chemical composition and hardness of the stalk were measured. In trial 2, quinoa stalk was inoculated with PO, and incubated at 10 and 25 °C for 60, 90 and 120 days. After incubation, the chemical composition and hardness of the stalk were measured. In trial 1, acid detergent lignin (ADL) content in the stalk decreased in both treatments, and the ADL content was lower in PO than in PC. However, the hardness of the stalk after incubation was weaker in PC. In trials 2, ADL content and hardness of the quinoa stalk decreased under both incubation temperatures, but the decrease rates of the ADL content and the hardness were slower in the stalks incubated at 10 °C. After 120-day incubation, the ADL content was higher in the stalk incubated at 10 °C compared with the stalk incubated at 25 °C, but the hardness did not differ between the incubation temperatures. These results indicate the possibility of improving the feeding value of quinoa stalk by white rot fungi treatment under a cool climate condition such as Andean highlands.

Introduction

Livestock production by llamas and sheep is conducted in the Andean highlands, but feed resources are scarce due to the cool and dry climate. Quinoa is an important food crop in the Andean highlands, but its use for animal feed is limited because of its high lignin content and hardness. Recently, it is expected that quinoa can contribute to the restoration of food production in areas where salt accumulation has progressed, such as Middle East, North Africa and Central Asia regions (Choukr-Allah *et al*., 2016). In most of these areas, not only food resources but also feed resources are limited, so quinoa stalk is expected to use for animal feed. White rot fungi of edible mushrooms have lignin-degrading enzymes, and white-rot fungi such as *Pleurotus* spp. is able to improve the nutritional value of the feed by reducing lignin content. The inoculation of white rot fungi on the lignified agricultural by-products such as wheat straw, bagasse, maize stover and rice straw has shown improvement in their nutritional value (Kewalramani *et al*. 1988; Fazaeli *et al*., 2002; Okano *et al*., 2007; Tuyen *et al*., 2013; Khan *et al*., 2015). Therefore, it can be expected that the feeding value of the quinoa can be improved by white rot fungi treatment.

Methods and Study Site

Trial 1: Two types of quinoa stalks harvested in Kyoto Japan were used. One is highland type and another one was hybrid type. The stalks were cut to about 10 cm length and was adjusted to a moisture content of 65% by soaking the stalk in water for 24 hours. After the moisture adjustment, the stalks were stuffed in the mushroom bottle, and sterilized by an autoclave (121 ℃, 20 min). Then, the stalk was inoculated with grain spawn of *Pleurotus ostreatus* (PO) or *Pleurotus citrinopileatus* (PC) at the rate of 5 % by fresh weight of the stalk. The inoculated quinoa stalk bottles were incubated for 90 days in a bucket. Temperature and humidity during incubation were allowed to fluctuate. After incubation the stalks were dried and analysed for chemical composition and hardness.

Trial 2: Quinoa stalk harvested in Hokkaido Japan was cut to about 10 cm length and was adjusted to a moisture content of 65% by soaking the stalk in water for 24 hours. After the moisture adjustment, the stalks were stuffed in the mushroom bottle, and sterilized by autoclave (121 ℃, 20 min). Then, the stalk was inoculated with grain spawn of PO at the rate of 5 % by fresh weight of the stalk. The bags including the inoculated quinoa stalk were incubated in an incubator maintained at 10 ℃ and a room with an average temperature of 25 ℃ for 60, 90 and 120 days. After incubation the stalks were dried and analysed for chemical composition and hardness.

Results

In trial 1, the cellulose, hemi-cellulose and acid detergent lignin (ADL) contents in dry matter of the highland type and the hybrid type of the quinoa stalks were 63.7 %, 16.2 %, 7.4 % and 61.3 %, 15.6 %, 9.0 %, respectively. The average temperature and humidity during incubation were 25.1 ℃ and 68.3 %, respectively. After incubation, cellulose, hemi-cellulose and ADL contents in dry matter of the highland type of quinoa stalk inoculated with PO and PC were 58.0%, 7.4 %, 3.5 % and 50.2 %, 7.6 %, 5.1 %, respectively, and those of the hybrid type of quinoa stalk inoculated with PO and PC were 60.3 %, 5.5 %, 6.1 % and 53.4 %, 5.5 %, 7.4 %, respectively. The ADL contents of the both type of quinoa stalk decreased with white rot fungi treatment ($P < 0.05$), and the ADL content after incubation was lower in the stalk inoculated with PO than in PC ($P < 0.05$). The cellulose and hemi-cellulose contents in the both type of the quinoa stalk also decreased with the white rot fungi treatment ($P < 0.05$). The hemi-cellulose content in the both type of quinoa stalk did not differ between PO and PC inoculation, but the cellulose content was lower in the stalk inoculated with PC than that inoculated with PO ($P < 0.05$). The hardness of the intact quinoa stalk did not differ between the type and averaged 11.5 kgf/cm^2. After incubation, the hardness of the highland type of the quinoa stalk inoculated with PO and PC were 4.3 kgf/cm^2 and 2.9 kgf/cm^2, respectively, and that of hybrid type of quinoa stalk inoculated with PO and PC were 4.6 kgf/cm^2 and 2.1 kgf/cm^2, respectively. The hardness of the both types of the quinoa stalk were decreased by white rot fungi treatment, and the effect of reducing hardness was greater with PC than with PO ($P < 0.05$).

In trial 2, the cellulose, hemi-cellulose and ADL contents in dry matter of the quinoa stalk were 56.0 %, 19.2 %, and 10.9 %, respectively. The average temperature and humidity in the room and the incubator during the incubation was 23.9 ℃ and 72.1 %, and 9.1 ℃ and 76.5 % respectively. The ADL content in the quinoa stalk incubated under both temperature condition decreased with white rot fungi treatment ($P < 0.05$) and decreased as incubation period became longer ($P < 0.05$). However, the ADL content of the quinoa stalk after 120 days incubation was higher in low temperature condition (8.2 %) than in high temperature condition (6.9 %; $P < 0.05$). The cellulose and hemi-cellulose contents also deceased by white rot fungi treatment ($P < 0.05$), but their contents after incubation were not affected by the temperature during the incubation. The average cellulose and hemi-cellulose contents after 120 days incubation was 50.9 % and 15.1 %, respectively. The hardness of the quinoa stalk used in trial 2 was 14.7 kgf/cm^2. The hardness of the quinoa stalk decreased with white rot fungi treatment ($P < 0.05$), but it was not affected by the incubation temperature. The hardness after 120 days incubation under high and low temperature condition was 2.9 kgf/cm^2 and 3.6 kgf/cm^2, respectively.

Discussion

Similar to previous reports (Kewalramani *et al.* 1988; Fazaeli *et al*., 2002; Okano *et al*., 2007; Tuyen *et al*., 2013; Khan *et al*., 2015), white rot fungi treatment has been shown to reduce the lignin content in the quinoa stalk by this study. This study also showed that reduction of the hardness of quinoa stalks by the white rot fungi treatment. As ADL content in feed and reduction rate of particle size in the rumen are closely related with feed intake, especially low-quality feed, the decrease of ADL content and the reduction of the hardness by white rot fungi treatment probably contribute the improvement of intake of lignified feed. Yamakawa *et al*. (1992) reported that voluntary intake of rice straw by sheep was increased by white rot fungi treatment. It was also demonstrated that the effect of white rot fungi treatment is affected by incubation condition such as the species of fungi and incubation temperature. From the point of view of degradation of ADL in feed, PO was superior to PC. It has been reported that the ability of white rot fungi to degrade lignin differs depending on the species of white rot fungi (Kewalramani *et al*. 1988; Taniguchi *et al*., 2005). In the report of Kewalramani *et al*. (1988) who treated bagasse with several white rot fungi, and *Polyporus hirsutus* had the highest ability to degrade lignin and had a large effect of improving digestibility. On the other hand, PC was superior to PO in the ability to degrade cellulose and to reduce the hardness. The hardness of incubated quinoa stalk was positively associated with cellulose content in the stalk ($r = 0.644$, $P < 0.05$), but no significant correlation was observed between the hardness and ADL content in the stalk. It was thought that lignin degradation and brittleness of the quinoa stalk by white rot fungi may be independent functions. The ADL content of the incubated quinoa stalk was affected by incubation temperature, and was higher in the stalk incubated low temperature. However, the cellulose content and the hardness of the quinoa stalk were not affected by incubation temperature.

This study shows the possibility decrease of ADL content and the brittleness of quinoa stalk by white rot fungi treatment. Although these abilities of white rot fungi treatment depend on the incubation condition such as type of fungi and incubation temperature, this study demonstrate that white rot fungi treatment may improve feeding value of quinoa stalk even in cool environments such as the Andean highlands.

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