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Araştırma
(Research)

Enrichment of nutritional composition of sesame seed by solid-state fermentation using four *Aspergillus niger* strains*

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*This study is an expanded version of the paper titled "Nutritional enrichment of sesame seed by *Aspergillus niger* solid-state fermentation" presented at the III. Balkan Agriculture Congress held in Edirne, Turkey, on 29 August-1 September 2021.

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Abstract

Objective: This study was conducted to determine the effect of solid-state fermentation using four different *A. niger* strains on the nutritional composition of sesame seed.

Materials and Methods: The mixture of four different *Aspergillus niger* strains (ATCC 200344, ATCC 200345, ATCC 201572, and ATCC 52172) was used in the solid-state fermentation. Sesame seed was sterilized at 121 °C for 15 min by autoclave before fermentation. A nutritional salt (glucose: urea: $(NH_4)_2SO_4$: peptone: KH_2PO_4: $MgSO_4.7H_2O$= 4: 2: 6: 1: 4: 1) was added to sesame seed to support the growth of *A. niger* strains. Sesame seed was inoculated by the mixture of *A. niger* strains (at 1 mL of 10^6 spores/mL for every 100 g) and incubated at 30 °C for seven days. Unfermented and fermented sesame seed were analyzed for determination of the crude protein, ether extract, ash, neutral detergent fiber, acid detergent fiber, and acid detergent lignin content.

Results: The crude protein and ash contents of sesame seed were increased (P<0.001 and P<0.01, respectively) by the mixture of *A. niger* strains. However, solid-state fermentation decreased the ether extract (P<0.05), cellulose (P<0.001), hemicellulose (P<0.001), neutral detergent fiber (P<0.001), acid detergent fiber (P<0.01), and acid detergent lignin (P<0.05) content of sesame seed.

Conclusion: The obtained results showed that the nutritional composition of sesame seed can be enriched through solid-state fermentation using a mixture of *A. niger* strains.

Keywords: Sesame seed, nutritional enrichment, solid-state fermentation, fermented feed, *Aspergillus niger*, *Sesamum indicum* L.

Susam tohumunun besin madde kompozisyonunun dört Aspergillus niger suşları kullanılarak gerçekleştirilen katı kültür fermantasyonu ile zenginleştirilmesi

Öz

Amaç: Bu çalışma dört *A. niger* suşu karışımı ile gerçekleştirilen katı kültür fermantasyonunun susam tohumunun besin madde kompozisyonu üzerine etkilerinin araştırılması amacıyla gerçekleştirilmiştir.

Materyal ve Yöntem: Katı kültür fermantasyonunda dört farklı *Aspergillus niger* suşu (ATCC 200344, ATCC 200345, ATCC 201572 ve ATCC 52172) karışımı kullanılmıştır. Katı kültür fermantasyonundan önce susam tohumu otoklav ile 121 °C'de 15 dakika steril edilmiştir. *Aspergillus niger* gelişimini teşvik etmek amacıyla susam tohumuna besinsel tuz (glucose: urea : $(NH_4)_2SO_4$: peptone: KH_2PO_4: $MgSO_4.7H_2O$=4: 2: 6: 1: 4: 1) eklenmiştir. Susam tohumu *A. niger* suşları karışımıyla (1 ml 10^6 spor/ml'lik süspansiyon/ 100 g) inoküle edilmiş ve 30 °C'de 7 gün inkübe edilmiştir. Susam tohumu ve fermente susam tohumunun ham protein, ham yağ, ham kül, nötr deterjanda çözünmeyen lif, asit deterjanda çözünmeyen lif ve asit deterjanda çözünmeyen lignin düzeyi belirlenmiştir.

Araştırma Bulguları: Katı kültür fermantasyonuyla susam tohumunun ham protein (P<0.001) ve ham kül (P<0.01) düzeyi artış göstermiştir. Buna karşın, susam tohumunun ham yağ (P<0.05), selüloz

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(P<0.001), hemiselüloz (P<0.001), nötr deterjanda çözünmeyen lif (P<0.001), asit deterjanda çözünmeyen lif (P<0.01), ve asit deterjanda çözünmeyen lignin (P<0.05) düzeyi azalmıştır.

Sonuç: Çalışmadan elde edilen bulgular *A. niger* suşlarıyla gerçekleştirilen katı kültür fermantasyonunun susam tohumunun besinsel kompozisyonunu iyileştirebileceğini göstermiştir.

Anahtar Kelimler: Susam, besinsel zenginleştirme, katı kültür fermantasyonu, fermente yem, *Aspergillus niger*, *Sesamum indicum* L.

Introduction

Sesame (*Sesamum indicum* L.) seeds are important oilseed crops in human and animal nutrition (Lee et al., 2010). It is one of the most ancient oilseed crops and has been cultivated in Asia and Africa for a long time (Makinde and Akinoso, 2014). Sesame seeds are produced at 6.8 million tonnes worldwide (FAO, 2020). Sesame seed contains 50% lipid, 20% crude protein (CP), and 14% carbohydrate (Bae et al., 2016). It is also a rich source of vitamins and minerals (Hajimohammadi et al., 2020).

Solid-state fermentation (SSF) refers to the development of microorganisms within moistened solid substrates without free water (Gungor and Erener, 2020). The fermentation method can be used to improve the nutritional composition of agricultural products (Altop, 2019). Hajimohammadi et al. (2020) reported that solid-state fermentation using *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* increased the CP and amino acid content, and decreased the crude fiber (CF) content of sesame seed meal. Similarly, Olude et al. (2016) stated that *Lactobacillus plantarum* improved the nutritional composition of sesame seed meal. *Aspergillus niger* is also one of the preferred microorganisms in solid-state fermentation studies because of its growth ability on moistened substrates (Gungor et al., 2021a). Rajesh and Raj (2010) reported that *A. niger* increased the CP, amino acid, and ash content of various vegetable wastes containing sesame seed. This study aimed to determine the effects of solid-state fermentation using *A. niger* on the nutritional composition of sesame seeds.

Material and Method

Solid-state fermentation was performed with three replicates, according to Gungor et al. (2021b). *Aspergillus niger* strains (ATCC 200344, ATCC 200345, ATCC 201572, and ATCC 52172) were obtained from American Type Culture Collection (ATCC) and cultured in Potato Dextrose Agar. Sesame seed was sterilized at 121 °C for 15 min by autoclave. The nutritional salt (glucose: urea: $(NH_4)_2SO_4$: peptone: KH_2PO_4: $MgSO_4.7H_2O$=4: 2: 6: 1: 4: 1) were added to sesame seeds. After mixing, sesame seed was inoculated by the mixture of *A. niger* strains at 1 mL of 10^6 spores/mL per 100 g of sesame seed and incubated at 30 °C for seven days. Samples were dried at room temperature approximately 30-35 °C for 6 days until samples reached 90% dry matter (DM).

Sesame seeds were analyzed for DM, ash, crude CP, and ether extract (EE) contents according to AOAC (2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) analyses were conducted according to Van Soest et al. (1991). Hemicellulose content was calculated by subtracting the NDF from the ADF. Cellulose content was determined by subtracting the ADF from the ADL.

All experimental analyses were performed in triplicate. Data were analyzed with Student t test (SPSS 21.0 Statistics). Results were considered significantly different at $P < 0.05$.

Results and Discussion

Solid-state fermentation changed the nutritional composition of sesame seeds (Figure 1 and Figure 2). The CP and ash content were increased (P<0.001 and P<0.01, respectively) by the mixture of *A. niger* strains (Figure 1). However, solid-state fermentation caused decreases in EE (P<0.05, Figure 1), cellulose (P<0.001), hemicellulose (P<0.001), NDF (P<0.001), ADF (P<0.01) and ADL (P<0.05) of sesame seeds (Figure 2). Rajesh and Raj (2010) reported that *A. niger* increased the CP content of the mixture of various vegetable wastes, including sesame oil cake in solid-state fermentation conditions. Similarly, increased CP content was reported in the solid-state fermentation of sesame seed using *Pleurotus ostreatus* (Calvo-Lerma et al., 2022). The CP content of sesame seed meal was increased by *Lactobacillus acidophilus*, *Saccharomyces cerevisiae* (Hajimohammadi et al., 2020), and *Lactobacillus plantarum* (Olude et al., 2016). Sandhya et al. (2005) reported that *Aspergillus oryzae* produced protease in solid-state fermentation of sesame oil cake (Sandhya et al., 2005). Enzymes of the *A. niger* produced during solid-state fermentation may cause the increase in the CP of the sesame seed.

The ash content of sesame seed was increased after fermentation in this study. Similarly, *A. niger* rose the ash content of vegetable wastes with sesame seed (Rajesh and Raj, 2010). Gungor et al. (2021b) also

reported increased ash in grape seed by solid-state fermentation using *A. niger*. The increase in the ash content can be attributed to the consumption of organic materials by *A. niger* during fermentation (Rajesh and Raj, 2010). However, no change in the ash content of sesame seed was reported by *P. ostreatus* in solid-state fermentation (Calvo-Lerma et al., 2022). Besides, solid-state fermentation was also reported to decrease the ash content of sesame seed meal by *L. acidophilus*, *S. cerevisiae* (Hajimohammadi et al., 2020), and *L. plantarum* (Olude et al., 2016).

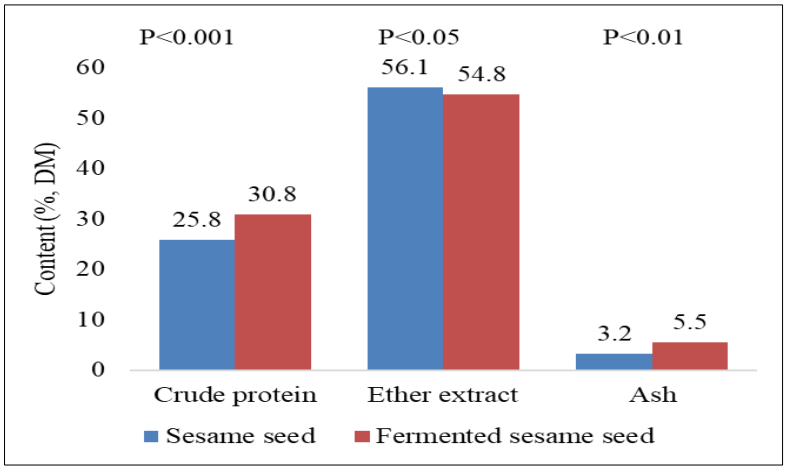

Figure 1. Crude protein and ash content of sesame seed and fermented sesame seed (%, DM)

Sesame seed is one of the important oil seed crops due to its high oil content (Lee et al., 2010). However, A. niger caused a decrease in EE content of sesame seed in the present study. Similarly, Rajesh and Raj (2010) reported a decreased EE in the mixture of various vegetable wastes, including sesame oil cake, by A. niger solid-state fermentation. Aspergillus niger was also reported to decline the EE content of sesame seed meal in solid-state fermentation (Olude et al., 2016). Rajesh and Raj (2010) explained the reduction in the EE content with the digestion of lipids from the substrate during fermentation, possibly for biomass production of A. niger. However, increased EE content after solid-state fermentation was also reported in sesame seed by P. ostreatus (Calvo-Lerma et al., 2022) and sesame seed meal by L. acidophilus and S. cerevisiae (Hajimohammadi et al., 2020).

Solid-state fermentation decreased the cellulose, hemicellulose, NDF, ADF and ADL of sesame seed in this study. Similarly, A. niger decreased the crude fiber content of various vegetable wastes, including sesame oil cake (Rajesh and Raj, 2010). The crude fiber of sesame seed meal was also decreased with solid-state fermentation using L. acidophilus, S. cerevisiae (Hajimohammadi et al., 2020), and L. plantarum (Olude et al., 2016). Bansal et al. (2012) showed that A. niger can produce cellulase and β-glucosidase enzymes with various herbal substrates. The decrease in the structural carbohydrates can be thanks to the degradation of cellulosic compounds by enzymes produced by A. niger during fermentation.

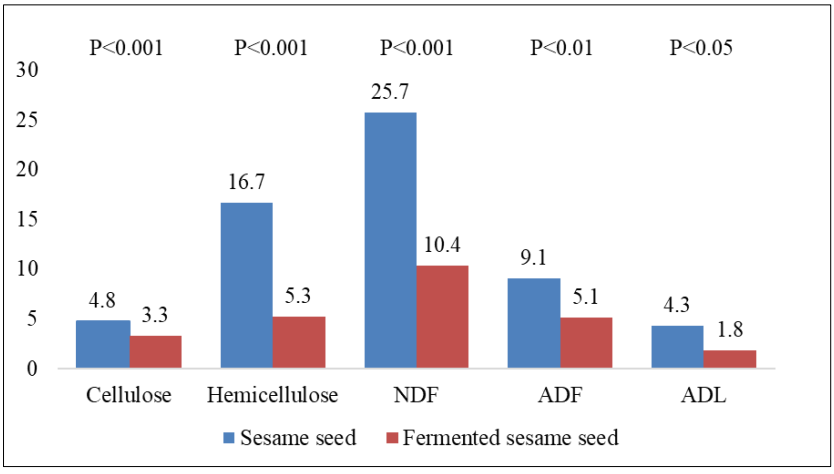

Figure 2. Cellulose, hemicellulose, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) content (%, DM)

Conclusions

Solid-state fermentation using a mixture of four different *A. niger* strains (ATCC 200344, ATCC 200345, ATCC 201572, and ATCC 52172) improved the nutritional composition of sesame seeds. The mixture of *A. niger* strains can be suggested for solid-state fermentation to convert sesame seeds into a more valuable feedstuff for animal nutrition.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Authorship contribution statement

AA, EG, and GE, conceptualization; AA and EG, data collection; GE, resources; EG, writing original draft; AA and GE, review & editing.

Kaynaklar

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