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Full Length Research Paper

Effects of magnetic fields pretreatment of mungbean seeds on sprout yield and quality

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The aim of this investigation was to determine the effect of magnetic field pretreatment of mungbean seeds on the yield and quality of sprout. The sprout elongation, biomass and nutrition ingredients (for example, concentration of soluble sugar, protein, vitamin C, etc.) were measured to test this effect of magnetic field. The results show that magnetic field stimulation caused 25, 9 and 5.4% increment in sprout elongation, fresh weight and dry weight compared with the control. Similarly, compared to the control, magnetic field pretreatment caused an increase by 12% in the concentration of spouts protein, by 5.1% in the concentration of spouts soluble sugar, by 13.8% in the concentration of spouts vitamin C, and by 113% in the concentration of anthocyanin concentration. Similarly, the concentration of arginine (Arg), histidine (His), lysine (Lys), phenylalanine (Phe), tyrosine (Tyr), leucine (Leu), isoleucine (ILe), glutamic acid (Glu), serine (Ser) and threonine (Thr) were also significantly increased by 600 mT magnetic field pretreatment. Therefore, the results suggest that 600 mT magnetic field can enhance the yield and quality of mungbean sprouts and can be applied to sprouts produce.

Key words: Magnetic field, mungbean sprout, sprout quality, nutrition components, vitamin C.

INTRODUCTION

The effects of magnetic field on living systems, particularly on seed germination and plant growth, have been reported by many researches. The first studies were conducted by Savostin (1930), who observed that magnetic field treatment could increase the rate of wheat seedlings elongation. Akoyunoglou (1964) reported that the activities of some enzymes were increased by magnetic field treatment. Pietruszewski (1993) also reported that the seedling growth, seed vigor and crop yield were increased when seeds were exposed to magnetic field. Piacentini et al. (2001) report testified that, magnetic field pretreatment had a positive effect on stimulating seedling growth and development of cucumber.

The use of germinated seeds as food originated in eastern countries and has spread to he western world where they are considered fashionable and healthy ingredients (Kuo et al., 2004). Consumers can find on the vegetable market an extraordinary variety of different types of sprouts including those from the following seeds: adzuki bean (*Phaseolus angularis*), alfalfa (*Medicago sativa*), broccoli (*Brassica oleracea convar. botrytis*), cress (*Lepidium sativum*), lentil (*Lens culinaris*), mungbean (*Phaseolus aureus*), white mustard (*Sinapis alba*), green and yellow pea (*Pisum sativum*), onion (*Allium cepa*), radish (*Raphanus sativus*), rice (*Oryza sativa L.*), rye (*Secale cereale*), sesame (*Sesamum indicum*), sunflower (*Helianthus annuus*) and wheat (*Triticum aestivum*) (Weiss and Hammes, 2005). They are consumed often raw or slightly cooked in salads and sandwiches (Weiss and Hammes, 2003), or as decorative appetizers. It is well known that the germination process improves the nutritional value and reduces antinutritional factors of sprouts compared with unprocessed seeds (Ziegler, 1995; VidalValverde et al., 2002). However, little is known whether magnetic field pretreatment can enhance the quality and yield of

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sprouts. So we put forward a hypothesis that magnetic field pretreatment can increase the yield and quality of sprouts. To test our hypothesis, the mungbean seed was exposed to magnetic field as a case study, and some yield parameters (for example, elongation, fresh weight and dry weight) and quality parameters (for example, the concentration of soluble sugars, soluble protein, Vitamins C, etc.) were measured. The main objectives of this study were to evaluate the potential biological effects of magnetic field on food nutrition improvement.

Practical Application

It is well known that the germination process improves the nutritional value and reduces antinutritional factors of sprouts compared with unprocessed seeds whether magnetic field pretreatment can enhance the quality and yield of sprouts is unknown. This study indicates that 600 mT magnetic field can enhance the yield and quality of mungbean sprouts. Results of this work may be useful for promoting the quality maintenance of fresh sprouts in practical.

MATERIALS AND METHODS

Materials and magnetic field pretreatment

Mungbean seeds were purchased from Xi'an seed market, Shaanxi province, China. The seeds were selected and randomly divided into 2 groups: (1) the control group (without treatment, CK); (2) seeds exposed to 600 mT magnetic field pretreatment (Model: 2G of 755R magnetometer system, 2G Co. Mountain View, CA, USA). At same time, similar old age sprouts were bought from the market as control to compare with the seeds exposed to magnetic field (Market). The biological effects of magnetic field pretreatment of mungbean seeds on germination and growth were described in previous study (Chen et al., 2011). The authors show that different doses of magnetic field had the different effects on the seed germination and the dose of 600 mT magnetic field is the best dose among the five treatments. Therefore, a dose of 600 mT magnetic field radiation was used in this study. Seeds treated with magnetic field were sown separately in five plastic dishes (Φ 25 cm, each containing 100 seeds) with wet filter paper soaked with distilled water and grown at 25°C at dark condition; every replicate experiment comprised three plastic pots.

Biochemical analysis

For protein extraction, 0.5 g mungbean sprouts (fresh weight) were homogenized at 0°C with 2.5 ml phosphate buffer of 0.1 M Tris-HCl (pH 8.0), 0.5 M sucrose, 0.06 M of L-ascorbic acid and 0.005 M of β-mercaptoethanol per 100 ml buffer). After thorough grinding, the samples were transferred to 5 ml centrifugation tube and centrifuged for 15 min at 8000 *g*. Protein concentration was measured according to Bradford (1976). 0.15 ml of supernatant sample was removed with a pipette, and 0.85 ml of distilled water and 5 ml of 0.1g l^{-1} G-250 Coomassie brilliant blue were added. After 15 min, the absorbance was determined at 595 nm. Standard curve was prepared by adding bovine serum albumin (Sigma, ultra 99%), ranging in concentration from 0 to 100 μg ml^{-1}. Concentration of soluble protein was expressed as mg g^{-1} FW.

Concentration of soluble sacchrides was measured according to Chen et al. (2002). Samples of mungbean sprouts (0.5 g dry weight) were blended with 30 ml 80% alcohol, extracted 30 min at 78°C, and then the samples were transferred to centrifuge tubes and clarified by centrifugation 800 *g* for 15 min, then supernatant sample was removed, and residue was extracted again. Finally, all supernatant samples were fixed to 25 ml with 80% alcohol. 0.1 ml sample was taken with pipette to 10 ml test tube and combined with 0.9 ml distilled water and 3 ml anthrone; reacted at 100°C for 10 min. Absorbance was determined at 620 nm. Concentration of soluble sacchrides was expressed as mg g^{-1} DW.

Concentration of vitamin C was measured according to Tonomura et al. (1978). 0.2 g samples (fresh weight) were randomly taken from 6-day-old sprouts. Samples were homogenized in a mortar with silica, NaCl and 10% metaphosphoric acid and subsequently centrifuged at 6500 *g* for 3 min. A supernatant sample was taken and diluted to 25 ml with redistilled water from which a 0.5 ml aliquot was removed and 1 ml of citric acid–phosphoric acid buffer (pH 2.3) followed by 1 ml of 2,6-dichlorophenol indophenol (30 mg l^{-1}). Thirty seconds later, the speed of absorbance change was determined over 10 min at 524 nm. Vitamin C concentration was expressed as μg g^{-1}FW.

Anthocyanin concentration was measured according to Zhang (1993). The sprouts (fresh weight 0.5 g) were extracted in 15 ml acidified methanol (methanol-water-hydrochloric acid, 79:20:1, v/v). Extract absorbance was measured with a spectrophotometer (TU-1810, Beijing Purkinje General Instrument Co., Ltd., China).

The samples for amino acid analysis were collected and freeze-dried. Concentrations of amino acid (AA) of sprouts were measured using the method outlined by Lyndon and Houlihan (1993) and validated by Mente et al. (2002). Briefly, amino acid was extracted from 500 mg sprouts by homogenizing in 10 ml absolute ethanol in the presence of 2.5 mM norleucine as internal standard. Samples were then made to 12.5 ml with water and amino acid were separated by centrifugation at 6000 *g* for 10 min. amino acid were determined with an automatic analyser (121MB, Beckman, USA), and results were calculated as milligrame per gram dry weight of sprout.

The length was measured with ruler; 10 sprouts were measured as fresh weight (g) and 10 sprouts drying at 80°C were measured as dry weight with electronic analytical balance (FA1004, Shanghai, China).

Statistical analysis

Samples were arranged in completely randomized designs with three replications. The data were presented using both the mean value [mean ± standard deviation (SD)]. Statistical significance was determined according to Duncan's multiple range tests at $P<0.05$.

RESULTS

Figure 1 shows the effect of magnetic field treatment seeds on the elongation (Figure 1a), fresh weight (Figure1b), dry weight (Figure 1c) and water concentration in tissue (Figure 1d) in the mungbean spouts. Compared to the control, magnetic field caused an increase by 25% ($P<0.05$) in the elongation of spouts, 9% ($P<0.05$) in the fresh weight and 5.4% ($P<0.05$) in the dry weight; compared to the market sprouts which had similar old age as the experiment sprouts, the seeds exposed to magnetic field treatment resulted in 36.9% ($P<0.05$) increase in the elongation, 0.6% ($P>0.05$)

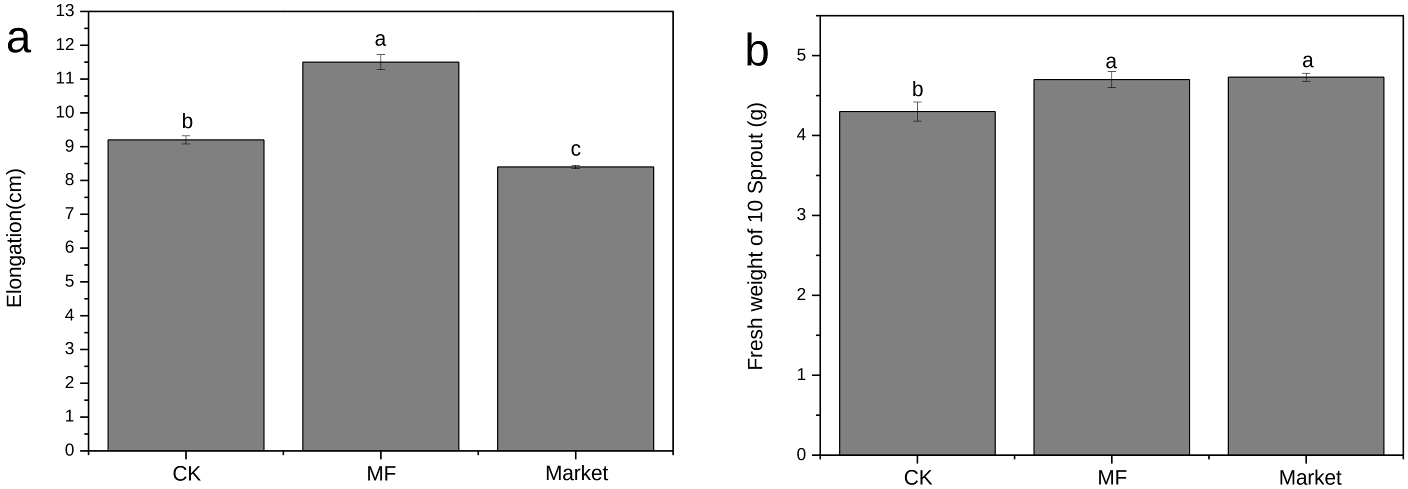


Figure 1. Effect of magnetic field treatment seeds on the elongation (a), fresh weight (b), dry weight (c) water concentration in tissue (d) in the mungbean spouts. CK, the control group; MF, magnetic field treatment group; Market, same old day sprouts bought from market. Data are mean ± S.D of three independent experiments. Bars with the same letter in column indicate insignificant difference from control at the level of 0.01 according to student's t-test.

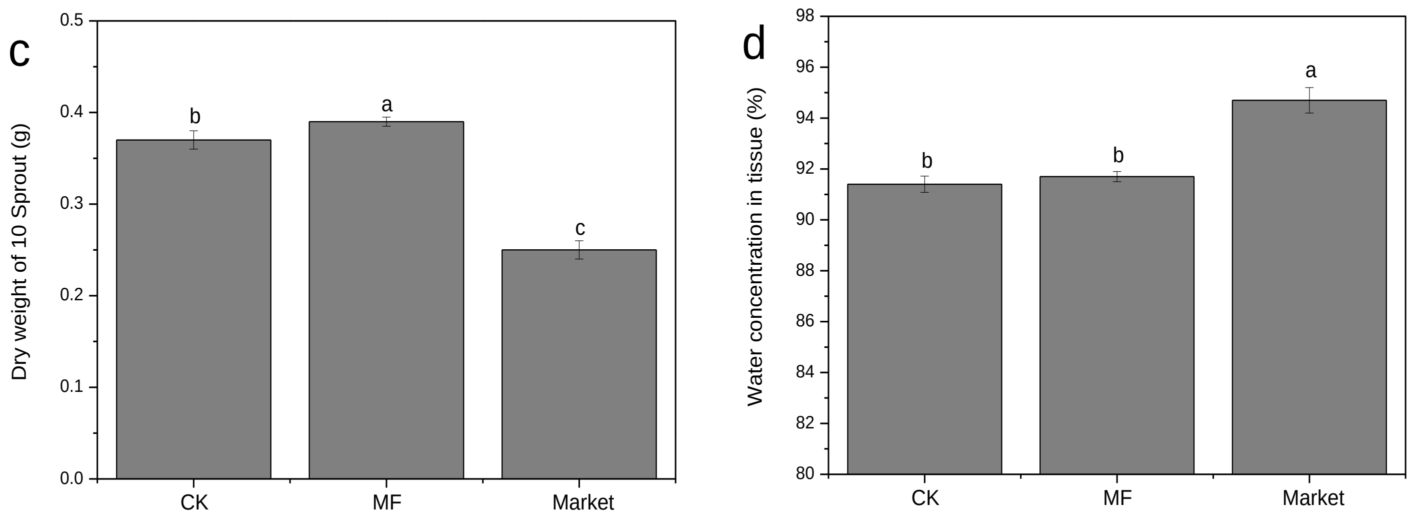


Figure 1. Contd.

increase in the fresh weight and 56% ($P<0.05$) increase in the dry weight. The elongation of spouts and the dry weight of the market sprouts were 8.6% ($P<0.05$) and 32% ($P<0.05$) lower than that of the control, but the fresh weight in market sprouts was 10% ($P<0.05$) higher than that of the control. As for the water concentration in tissue, the market spouts was 3% higher ($P<0.05$) than that of magnetic field spouts, and the control spouts was lower ($P>0.05$) than that of the magnetic field spouts.

Compared to the control, magnetic field pretreatment caused an increase by 12% ($P<0.05$) in the concentration of spouts protein (Figure 1a), by 5.1% ($P<0.05$) in the concentration of spouts soluble sugar (Figure 1b), by 13.8% ($P<0.05$) in the concentration of spouts vitamin C (Figure 1c) and by 113% ($P<0.05$) in the concentration of anthocyanin concentration (Figure 1d). No significant changes were observed in the concentration of crude fiber (data not shown) between the magnetic field treatment groups and the control group. Compared to the market sprout, the seeds exposed to magnetic field treatment showed 50% ($P<0.05$) increment in the concentration of spouts protein, 30% ($P<0.05$) increment in the concentration of spouts soluble sugar, 94% ($P<0.05$) increment in the concentration of spouts vitamin C and 25% ($P<0.05$) increment in the concentration of anthocyanin concentration (Figure 1d).

Meanwhile magnetic field pretreatment improved the protein disassemble and presented an increase in the

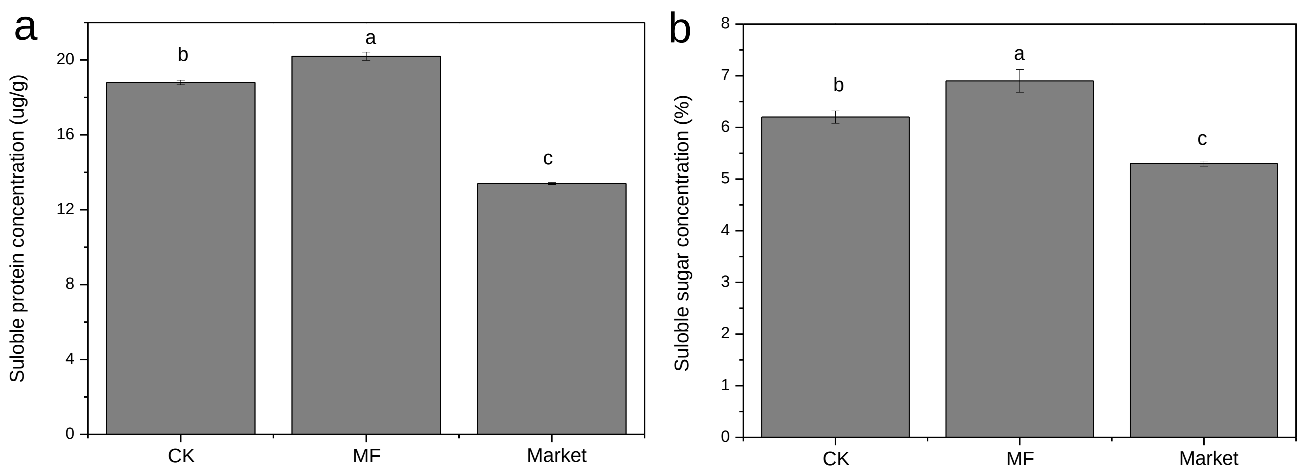
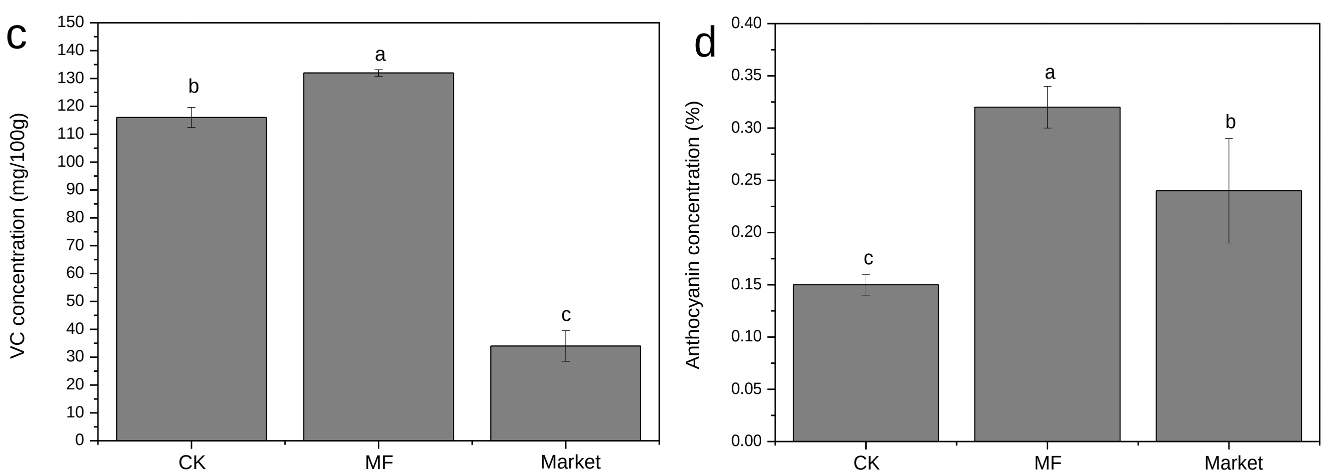


Figure 2. Effect of magnetic field on the concentration of soluble protein (a) soluble sugar (b) vitamin C (c) anthocyanin content (d) in the mungbean spout. CK, the control group; MF, magnetic field treatment group; Market, same old day sprouts bought from market. Data are mean ± S.D of three independent experiments. Bars with the same letter in column indicate insignificant difference from control at the level of 0.01 according to student's t-test.



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concentration of Arg (*P<0.01*), His (*P<0.01*), Lys (*P<0.01*), Val (*P>0.01*), Ala (*P>0.01*), Glu (*P<0.01*), Ser (*P<0.01*), Thr (*P<0.01*), Asp (*P<0.01*) except for Met, Cyr, Gly, Pro (Figure 3).

DISCUSSION

Sprouts are produced in hydroponic culture by soaking the seeds in water followed by incubation in a warm, humid environment to optimize germination and sprout growth. The nutritional content of dry seeds is increased after the seeds germination and growth of the sprouts (Rajkowski and Thayer, 2000). Sprouts are very popular for consumer due to its health food and inexpensive source of dietary nutrition (for example, proteins, (*P<0.01*), Phe (*P<0.01*), Tyr (*P<0.01*), Leu (*P<0.01*), Ile carbohydrates and minerals) and vitamins. In all over the world, especially in eastern countries, consumers can find on the vegetable market an extraordinary variety of different types of sprouts. Chinese people like this sprouts not only because it include some nutrition values for human health (proteins, carbohydrates, minerals and vitamins and so on), but also because those compositions have important functions for human health such as its detoxifying, anti-inflammatory, antitumourogenic and diuretic properties (Guan-Hong et al., 2006). Due to the fact that lot of sprouts are been consumed, some lawless businessman in China are applying fertilizer to improve sprouts yield and economy benefit. Therefore, food safety in China is a very ghastliness question. We found that the quality of

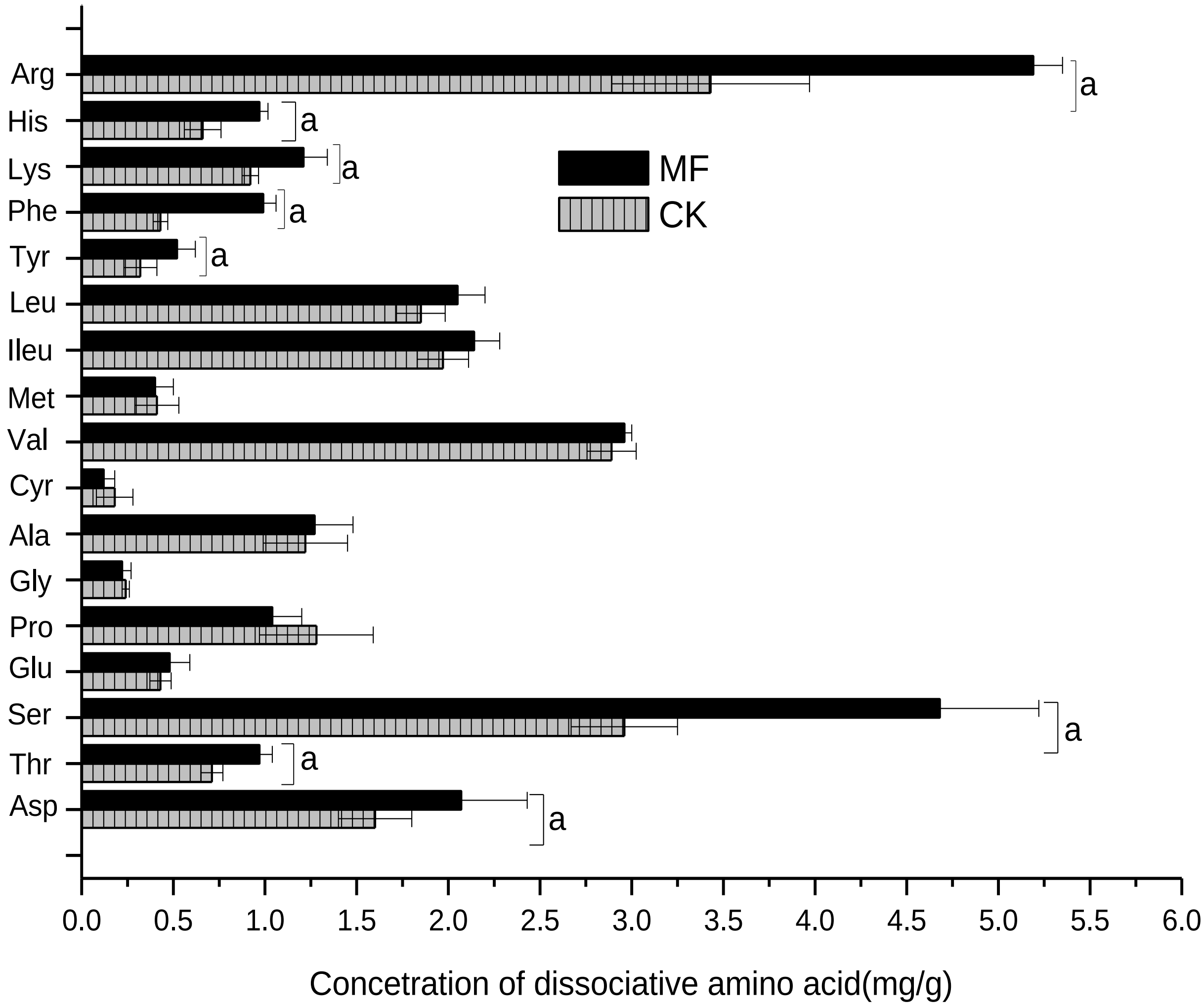

Figure 3. Effect of magnetic field on the concentration of dissociative amino acid in the mungbean spouts. CK, the control; MF, magnetic field treatment. Data are mean ± S.D of three independent experiments. Two bars with a letter in column indicate significant difference from control at the level of 0.05 according to student's t-test.

markets sprouts was less than that of same old age sprouts cultured in lab (Figures 1 and 2). The water in the tissue was distinctly higher, and the concentration of soluble protein, soluble sugar and vitamin C were significantly lower in the market sprouts than that in the experiment sprouts. Therefore, how to increase the quality and yield and guarantee food safety are very important for food produce. Waje and Kwon (2007) reported that irradiation at appropriate doses could be an effective intervention strategy against the pathogen contamination of sprouts. In general, gamma irradiation was more efficient than electron beam in terms of pathogen inactivation in sprouts. However, the effect of gamma ray and electron beam irradiation on the seed viability and nutritional quality of sprouts were not determined in their paper. Previous studies indicate that application of heat and chemical disinfectants could eliminate the pathogens in sprouts and seeds (Waje and Kwon, 2007). The use of ionizing radiation could completely eliminate various food borne pathogens from both seeds and sprouts (Buck et al., 2003). Peñas et al. (2010) also reported that high pressure enhanced the effectiveness of disinfectant agents to inactivate natural microbial populations in mungbean sprouts. The pressurizations at 250 MPa of mungbean seeds treated with hypochlorite (18000 ppm) or carvacrol carvacrol (1500 ppm) led to a significant inactivation of all natural microbial populations in sprouts. Although, the combination treatment of disinfectant agents and high pressure resulted in microbial inactivation and brought about a significant reduction in germination ratio, we did not investigate whether or not it reduced the quality of nutrition valuable.

Previous studies indicate that suitable magnetic field could speed up cucumber seed germination rate, seedling development and increase total biomass; similar results were also reported in cauliflower and tomato (Souza et al., 1999; Martinez et al., 2000). Exposure of dry sunflower seeds and maize seeds to static magnetic fields significantly increased germination, germination speed, and seedling growth (Vashisth and Nagarajan, 2010). The sprout elongation, the fresh weight and some nutrition parameters (the concentrations of soluble protein, soluble sugar, vitamin C and anthocyanin) were selected as parameters to test the effects of magnetic field on nutrition valuable and yield of sprouts in this study. This study indicates that magnetic field pretreatment could improve the yield and quality of sprouts, by improving the growth and nutrition accumulation of the concentrations of soluble protein, soluble sugar, vitamin C and anthocyanin in sprouts. The underlying mechanism might be, magnetic field irradiation causes an increase in certain enzyme activities such as amylase and proteinase, and results in increment in the decomposition rates of amylum and protein. Consequently, the biochemical and physiological metabolisms of the plants receiving magnetic field pretreatment accelerated, and the concentration of soluble protein, soluble sugar, vitamin C, and anthocyanin in sprouts were improved. However, the underlying mechanism of magnetic field pretreatment needs to be further investigated.

In conclusion, magnetic field pretreatment of mungbean seeds could improve the elongation, fresh weight and dry weight, the concentration of spouts protein, soluble sugar, vitamin C and anthocyanin concentration. Moreover, magnetic field pretreatment also improved the concentration of arginine (Arg), histidine (His), lysine (Lys), phenylalanine (Phe), tyrosine (Tyr), leucine (Leu), isoleucine (ILe), glutamic acid (Glu), serine (Ser) and threonine (Thr). The results suggest that 600 mT magnetic field can enhance the yield and quality of mungbean sprouts and can be applied to sprouts produce.

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