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Application of Ultra Superheated Steam Technology (USST) to Food Grain Preservation at Ambient Temperature for Extended Periods of Time

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ABSTRACT

Food security has been of great concern in every nation irrespective of their developed or underdeveloped status. Post-harvest losses are common for almost all agricultural products; therefore, these commodities are a matter of concern for all nations. Super-heated steam drying is a drying technology where the drying takes place through direct contact between superheated steam and the product to be dried. This study was designed to determine the effectiveness of Ultra-superheated steam technology (USST) drying alone or USST drying followed by mixing with scallop powder (SP; 0.1%) to extend the shelf life of: 1) Peanuts; 2) Red wheat (small sized); 3) Broken maize kernels; 4) Mixed animal feed; and 5) Bengal gram/chickpea. It was observed that treatment with USST at 400 °C or 500 °C (actual contact temperature was 210 °C and 250 °C, respectively) for 15 seconds was sufficient to decontaminate the mold successfully. After 26 months of storage at room temperature, no such mold was evident visually compared to control samples, and the products appeared fresh. Furthermore, treatment with USST at 400 °C or 500 °C (actual contact temperature was 210 °C and 250 °C, respectively) for 15 seconds followed by mixing with scallop powder (SP; 0.1%) was sufficient to increase the shelf life of the food grains studied beyond three years under similar experimental conditions. However, the product did not appear fresh or attractive subsequent to the attachment of the SP powder. Increasing the USST temperature may further enhance the shelf life of the product. Therefore, these findings suggest that USST technology may extend the shelf life of food grain products. However, optimization of treatment time and temperature is required for food grains to be most efficiently stored.

KEYWORDS: Ultra-superheated steam technology (USST); Food grains; Preservation; Ambient temperature; Risk reduction; Food security.

ABBREVIATIONS: USST: Ultra-superheated steam technology; SSD: Super-heated drying; SP: Scallop Powder; USDA: United States Department of Agriculture.

INTRODUCTION

Post-harvest losses of agricultural commodities have been a problem for all developing countries, particularly those that are primary producers. In these countries, non-mechanized harvesting practices and traditional technologies are still primarily used. Because of these, the extent of post-harvest food commodity losses are alarming. In order to overcome food deficiencies, these countries have traditionally emphasized two lines of action, e.g., (a) reducing future demand by slowing population growth and (b) augmenting food supplies by increasing

production. But perhaps the third and most important option in this context - the reduction of post-harvest losses - has not been given proper consideration. In addition, no such suitable technology has been developed to reduce post-harvest losses or to extend the shelf life of agricultural products.^{1,2}

As well, farmers and manufacturers want to produce products that are healthy, tasty and functional as possible. At the same time, they seek higher returns from low-cost production, without any concessions to food safety or product quality. They also want to minimize the environmental impact of their production systems while maintaining maximum flexibility within these systems.^{3,4}

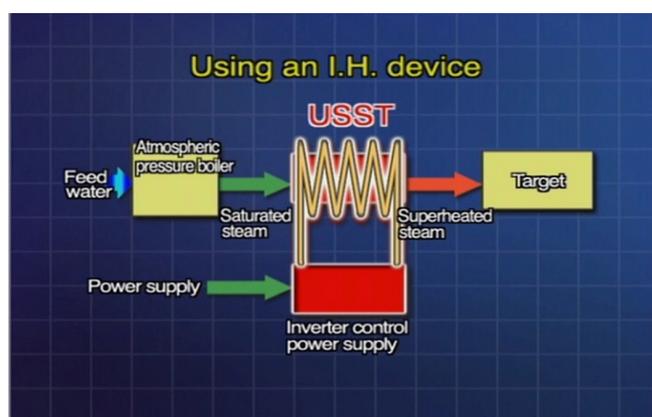
From ancient times, man has devised a number of ways to preserve food. In general, foods have been preserved by applying heat, cold, drying conditions, salt and fermentation techniques.³ Other advanced technologies for long-term storage are being developed, which may eliminate the extensive use of preservation chemicals. One such technology is the use of Ultra-superheated steam technology (USST), which is a modified version of a superheated steam technology.⁵

USST is a new, innovative technology that can be used to extend the shelf life of agricultural food products. Hausbrand introduced the idea of using Super-heated drying (SSD) at the beginning of the 20th century, however, it was not until the 1950's that researchers examined the process more closely.⁶ Following the 1970's oil crisis, a number of papers were published on the fundamental properties and applications of superheated steam drying.⁷ Conventional hot air drying is an energy-intensive operation which accounts for approximately 15% of industrial energy consumption in most industrialized countries.⁸ The recent modification to this process is described herein, making this an emergent technology with considerable advantages in energy savings, emissions reduction, fire and explosion prevention, and improved product quality.⁹

Superheated Steam: New Innovative Technology for Agricultural Product Disinfestations

Superheated steam is steam that is heated to a temperature that is higher than the boiling point of water. If saturated steam is heated at constant pressure, its temperature will rise, producing superheated steam. The newly developed Ultra Super-heated steam technology (USST; FBI Co. Ltd., Tokyo) continuously generates gas that consists of steam-originated electron radicals, in large scale, over a short time period under ordinary atmospheric pressure, through a specially designed high frequency current IH (induction heating) technology. "Steam-originated radicals" refers to highly active radicals of unpaired electrons, such as OH radicals (OH⁻), Hydrogen peroxide (HOOH), superoxide-anion radical (O₂⁻), and singlet oxygen (1O₂). In addition, ionized gaseous particles (H⁺, H⁻ and HO⁻), which are water vapour (H₂O) molecules, are generated from steam at 300 °C~500 °C temperature by using eddy cur-

rent energy under a specially designed high frequency current IH super-heating induction technology USST Apparatus. The use of traditional steam super-heating technology would require a very high-pressure vessel with extremely thick and heavy specially processed steel material, resulting in much higher machine-cost and a heavy/gigantic specification as well as the employment of a specially licensed machine-operator to generate the 500 °C super-heated steam. The USST is an oxygen free environment, which eliminates the possibility of systemic fire or explosion and could lead to improved product quality by the elimination of scorching. The heat generation mechanisms of USST are shown in Figure 1.



Heat generation mechanisms

Figure 1: Heat generation mechanisms of USST.

The objective of this study was to use USST technologies to reduce post-harvest losses of various agricultural commodities and to extend their shelf life at ambient temperature. The following agricultural products were studied: 1) Peanuts; 2) Red wheat (small sized); 3) Broken maize Kernels; 4) Mixed animal feed; and 6) Bengal gram/chickpea.

METHODS AND MATERIALS

Sample Collection

The following five samples were collected from different markets in Dhaka City, Bangladesh and used in this experiment. These samples were collected in sterilized Ziploc Bags and were transported to the Food Analysis and Research Laboratory, Center for Advanced Research in Sciences, University of Dhaka, and half of the samples were taken to the Research and Development Laboratory, JSP Inc. Ltd., Tokyo for USST treatments. In this study, low quality samples were chosen in the belief that if low quality products can be controlled, then good quality products can be controlled with less effort.

1) Peanuts: The worst quality rotten or damaged peanuts were purchased from the Kawran bazar market, Dhaka City, Bangladesh. These peanuts are usually thrown away or given to the poorest people.

2) Red wheat (small size): Red wheat (small sized) was pur-

chased from the Kawran bazar market, Dhaka City, Bangladesh. This small sized red wheat is usually used for flour production for low income people in Bangladesh.

3) Broken maize kernels: Broken Maize kernels were purchased from Nimtoli market, Dhaka City, Bangladesh. These broken maize kernels are generally used for poultry/fish feed production.

4) Mixed animal feed: Mixed animal feed was purchased from Nimtoli market, Dhaka City, Bangladesh. These mixed animal feeds are widely used in the poultry industry in Bangladesh.

5) Chickpeas: Bengal gram chickpeas were purchased from Nimtoli market, Dhaka City, Bangladesh. Bengal gram chickpeas are one of the cheapest sources of protein for the common people of south Asia.

Scallop Powder (SP)

Scallop powder is a novel biodegradable sanitizer that is obtained from the inner portion of the scallop (*Patinopecten yessoensis*) shell by baking it at 200 °C and then exposing it to excessive heat (1000 °C). After that, the shells are pulverized and passed through a micro sieve to obtain 5-15 µm particles of powder. This powder is said to have antibacterial and anti-fungal activity. As this powder is produced from natural sources, it does not pose a hazard to the environment, and it is biodegradable.¹⁰

Sample Treatment and Conditioning

The experiment was conducted on September 03, 2011, at the Research and Development Laboratory of JSP Inc., Ltd., Tokyo, Japan. All five samples were passed through the USST chamber at 400 °C or 500 °C for 15 seconds and stored at RT and sealed separately in polyethylene packages. The following five treatment categories were applied to each sample studied.

1. Control (no USST treatment); stored at RT in sealed polyethylene packages.
2. The samples were passed through the USST chamber at 500 °C for 15 seconds (actual contact temperature was 250 °C) and stored at RT in sealed polyethylene packages.
3. The samples were passed through the USST chamber at 400 °C for 15 seconds (actual contact temperature was 210 °C) and stored at RT in sealed polyethylene packages.
4. The samples were passed through the USST chamber at 500 °C for 15 seconds actual contact temperature was 250 °C then mixed with SP (0.1%) and stored at RT in sealed polyethylene packages.
5. The samples were passed through the USST chamber at 400 °C for 15 seconds (actual contact temperature was 210 °C)

then mixed with SP (0.1%) and stored at RT in sealed polyethylene packages.

After the experiment, a set of five treated and non-treated samples were kept at room temperature in the Japanese laboratory for future reference. Another set of treated and non-treated samples was transported back to the Dhaka laboratory and kept at room temperature for future reference.

RESULTS AND DISCUSSION

Peanuts

Peanuts are known by many other local names, such as earthnuts, ground nuts, goober peas, monkey nuts, pygmy nuts and pig nuts. Peanuts can be an important part of the diet, as they provide over thirty essential nutrients and phytonutrients.¹¹ In South Asia, peanuts are generally consumed as a light snack. They are usually roasted and salted (sometimes with the addition of chilli powder), or they may be sold roasted in the pod at road side or boiled with salt. Peanuts may be contaminated with the mold *Aspergillus flavus*, which produces a carcinogenic substance called aflatoxin. Lower quality specimens, particularly where mold is evident, are more likely to be contaminated. The United States Department of Agriculture (USDA) tests every truckload of raw peanuts for aflatoxins; peanuts containing more than 20 parts per billion of aflatoxins are destroyed.¹²

In this study, after 26 months of storage at RT, mold development was evident visually in the control sample, as shown in Figure 2. The mold was confirmed to be *Aspergillus flavus*, which produces carcinogenic aflatoxins. However, treatment with USST at 400 °C (actual contact temperature was 210 °C) for 15 seconds successfully decontaminated the mold, and after 26 months of storage, no mold was visually evident, and the products appeared fresh (Figure 2). Treatment with USST at 400 °C (actual contact temperature was 210 °C) for 15 seconds, followed by mixture with SP powder (0.1%), increased the shelf life of the peanuts by more than three years under similar experimental conditions. However, peanuts with residual SP powder did not retain an attractive appearance (Figure 2).

Therefore, this study demonstrated that the USST technology alone or USST treatment followed by mixture with scallop powder could be useful in extending the shelf-life of peanuts at ambient temperature.

Red Wheat (Small Size)

Wheat is one of the first cereals known to have been domesticated, and the ability of wheat to self-pollinate greatly facilitated the selection of many distinct domesticated varieties. Wheat is the world's most favored staple food, and it is grown on more than 240 million hectares, which is a larger area than for any other crop.^{13,14} There are many wheat diseases, mainly caused by fungi, bacteria, and viruses. Fungicides, used to pre-

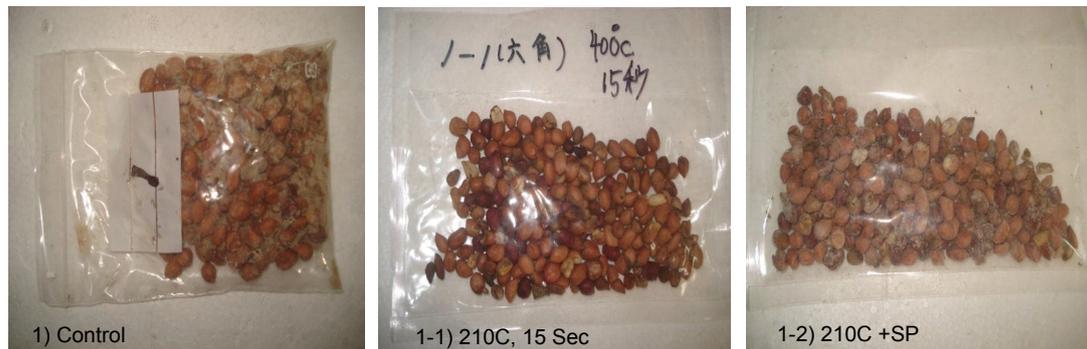


Figure 2: 1) Control; 1-1) USST Treated; and 1-2) USST treatment followed by mixture of SP powder (0.1%) with peanuts and kept at room temperature for >26 months.

vent significant crop losses from fungal disease, can be a significant variable cost in wheat production.¹³ Estimated production lost owing to plant diseases around the world vary between 10-25%. A wide range of organisms can infect wheat, of which the most important are viruses and fungi.¹⁵

In this study, the control sample was initially free of contamination, but mold development was visually evident after 26 months of storage at RT. The identity of this mold has yet to be confirmed. Treatment with USST at 500 °C (actual contact temperature was 250 °C) for 15 seconds successfully decontaminate the mold, and after 26 months of storage, no mold was visually evident, and the products appeared fresh (Figure 3). In addition, treatment with USST at 400 °C (actual contact temperature was 210 °C) for 15 seconds followed by mixture with SP (0.1%) extended the shelf life of red wheat by more than three years. No mold was visually evident, and the product did not look attractive (Figure 3) compared to non-SP treated samples.

Therefore, this study result also demonstrated that USST technology alone or USST treatment followed by mixture with scallop powder was effective in extending the shelf-life of red wheat (small size) at ambient temperature.

Maize Kernels (Broken)

Maize harvesting is a highly mechanized process in the developed world, while it is still done manually in developing countries. Changes in the physical quality of the grain are often a result of mechanical harvesting, shelling and drying. Storage stability depends on the relative humidity of the interstitial gases, which is a function of both moisture content in the kernel and temperature. Low moisture content and low storage temperatures reduce the opportunity for deterioration and microbial growth. Aeration therefore becomes an important operation in maize storage as a means of keeping down the relative humidity of interstitial gases. Significant maize losses have been reported in tropical countries.¹⁶ Losses of up to 10% have been found, not including those losses caused by fungi, insects or rodents. If these were included, losses could increase to 30% in tropical humid areas or to 10 to 15% in temperate areas. Losses due

to fungi (mainly *Aspergillus* and *Penicillium*) are important for both economic and health reasons because of aflatoxins and mycotoxins.¹⁶

The efficient conservation of maize, like that of other cereal grains and food legumes, depends basically on the ecological conditions of storage; the physical, chemical and biological characteristics of the grain, the storage period, and the type and functional characteristics of the storage facility.

In this study, the control sample deteriorated considerably, with mold development being evident within one month. Treatment with USST at 500 °C (actual contact temperature was 250 °C) for 15 seconds was initially successful at decontamination, however, a white mold was visually evident after four months of storage. However, treatment with USST at 400 °C and 500 °C (actual contact temperature was 210 °C and 250 °C, respectively) for 15 seconds followed by mixture with SP (0.1%) decontaminated the mold, and after 26 months of storage no mold was evident visually, and the products looked better as compared to the control sample (Figure 4). Therefore, this study demonstrated that the optimization of time and temperature is necessary to eliminate mold and extend the shelf life of maize kernels at ambient temperature.

Mixed Animal Feed

The chemical and nutritional constituents of animal feeds are important for livestock nutrition and growth, but they are only part of the animal feed matrix. From an ecological standpoint, harvested grains are not only ingredients for livestock diets, but they can act as substrate and transmission vectors for simple unicellular prokaryotic and eukaryotic organisms.¹⁷ Feeds may contain diverse microflora that are acquired from multiple environmental sources, including dust, soil, water, and insects. Feed materials may be contaminated at any time during their growth cycle, while being harvested, processed, stored or dispersed. The microflora found in feed materials come from a variety of ecological niches, such as the soil and the gastrointestinal tract, and they must adapt to the chemical and physical parameters inherent to the animal feed and feed components in



Figure 3: 2) Control; 2-1) USST Treatment at 250 °C ; 2-2) USST treatment at 210 °C followed by mixture with SP powder (0.1%); and 2-3) USST treatment at 250 °C followed by mixture with SP powder (0.1%). The treated and non-treated red wheat samples were kept at room temperature for > 26 months.

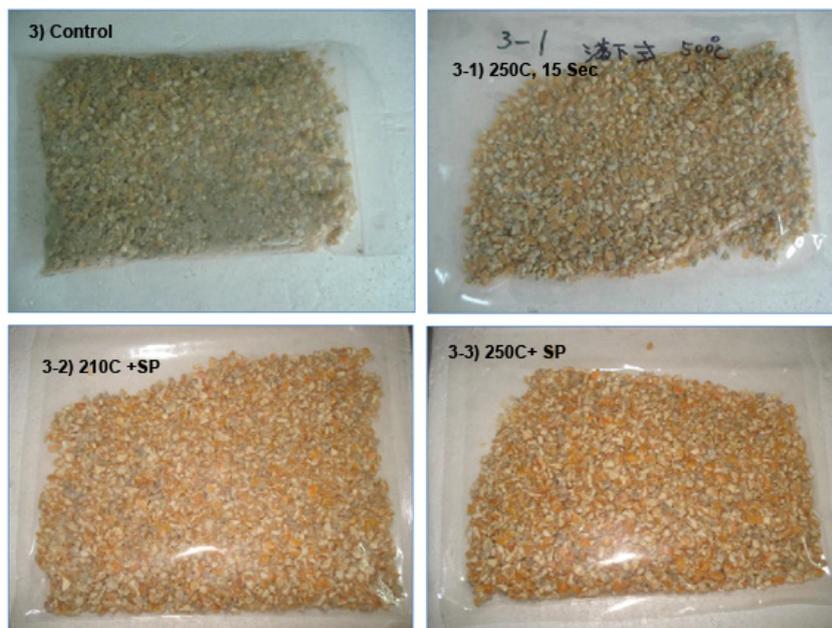


Figure 4: 3) Control; 3-1) USST Treatment at 250 °C ; 3-2) USST treatment at 2100C followed by mixture with SP powder (0.1%); and 3-3) USST treatment at 250 °C followed by mixture with SP powder (0.1%). The treated and non-treated broken maize kernels samples were kept at room temperature for > 26 months.

order to survive and/or grow. The microbial diversity found in different feeds depends on the water activity, oxygen tension, pH and nutrient composition of the feed matrix,^{17,18} and microbial growth is dependent upon the moisture content of the feed material. Some microorganisms, primarily moulds, have adapted to conditions without free water, and these microbes can actively grow in stored grains. However, the majority of microorganisms must exercise various strategies to survive until there is sufficient water content to support microbial activity. Microorganisms can decrease grain value through nutritional changes, physical dam-

age, or the production of toxins that are deleterious to animal health.^{17,18}

In this study, the control sample deteriorated appreciably, and mold development was evident visually within 25 days of storage at room temperature. However, treatment with USST at 500 °C (actual contact temperature was 250 °C) for 15 seconds effectively decontaminated the mold, and after 6 months of storage, no mold was visually evident. In addition, treatment with USST at 400 °C and 500 °C (actual contact temperature was 210

°C and 250 °C, respectively) for 15 seconds followed by mixture with SP (0.1%) successfully decontaminated the mold. After 26 months of storage, no such mold was evident, but the product's appearance was not attractive following mixture with SP powder (Figure 5)

Therefore, this study demonstrated that the USST technology alone, or the USST treatment followed by mixture with scallop powder, were useful in extending the shelf-life of mixed animal feed at ambient temperature.

Bengal Gram/Chickpea

Bengal gram is called Chickpea or Gram (*Cicer aritimum L.*) in South Asia. Bengal gram is a major pulse crop in Bangladesh, widely grown and consumed there for centuries. It is a protein-rich supplement to cereal-based diets, especially in poor and developing countries, where people are vegetarians or cannot afford animal protein. It offers the most practical means of eradicating protein malnutrition among vegetarian children and nursing mothers.¹⁹ Bengal gram, one of the cheapest sources of protein for the common people, is now increasingly becoming expensive and getting beyond the reach of a large portion of the population in Bangladesh and India. The share of Bengal gram production has been decreasing, particularly since the mid-sixties. Total production has been low due to poor productivity and inadequate post-harvest storage and processing facilities. Food grains are stored for varying lengths of time before consumption as food, feed or seed.²⁰ These are likely to be spoiled in storage by biological agents such as insects, mites, rodents, microorgan-

isms or by moisture. The extent of this damage varies with storage conditions and structure. Storage losses range from 20 to 30 percent, causing enormous losses not only to the farmers but also to the overall national agricultural production system.²¹

In this study, a control sample without the addition of SP was not tested due to the unavailability of Bengal gram during the experiment. Treatment with USST at 500 °C for 15 seconds decontaminated the mold, and after 26 months of storage, no such mold was evident, and the products appeared fresh. In addition, treatment with USST at 400 °C for 15 seconds followed by mixture with SP (0.1%) extended the shelf life of the Bengal gram for more than three years, with no mold being visually evident. However, the product did not appear to be fresh or attractive as a result of the attachment of SP powder (Figure 6). This finding also demonstrated that USST technology alone or USST treatment followed by mixture with the scallop powder could be useful in extending the shelf-life of Bengal gram/chickpea at ambient temperature.

CONCLUSION

This study demonstrated that Ultra-superheated steam (USST) alone or USST treatment followed by mixture with SP powder (0.1%) were both able to extend the shelf life of: 1) Peanuts; 2) Red wheat (small sized); 3) Broken maize kernels; 4) Mixed animal feed; and 5) Bengal gram/chickpea for more than 26 months at ambient temperature, depending on the particular food grain tested. Therefore, this finding suggests that USST technology can extend the shelf life of agricultural products,

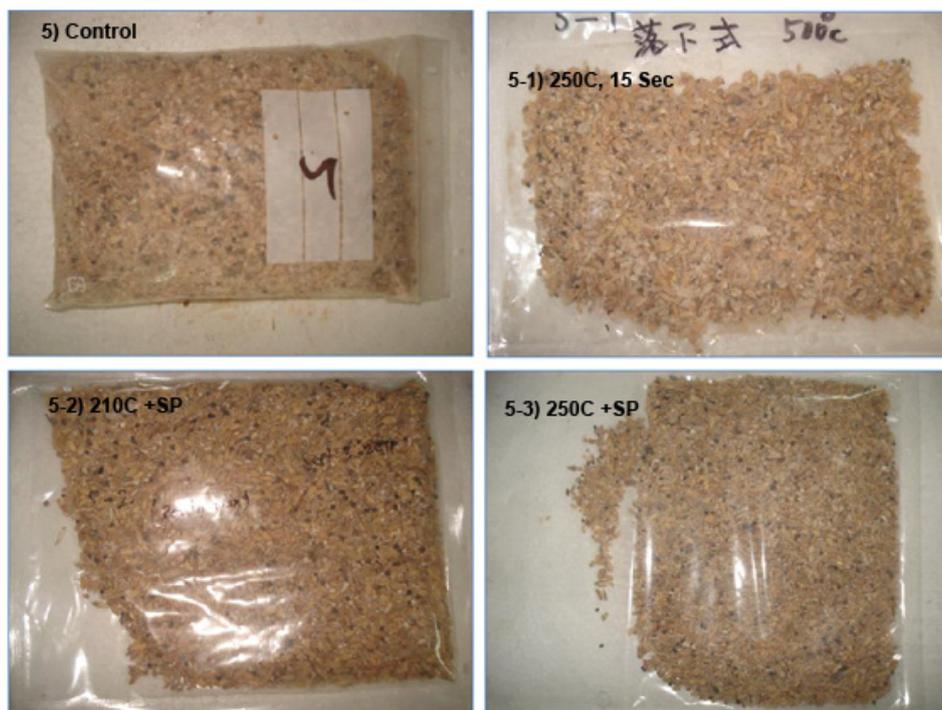


Figure 5: 5) Control; 5-1) USST Treatment at 250 °C; 5-2) USST treatment at 210 °C followed by mixture with SP powder (0.1%); and 5-3) USST treatment at 250 °C followed by mixture with SP powder (0.1%). The treated and non-treated mixed animal feed samples were kept at room temperature for > 26 months.

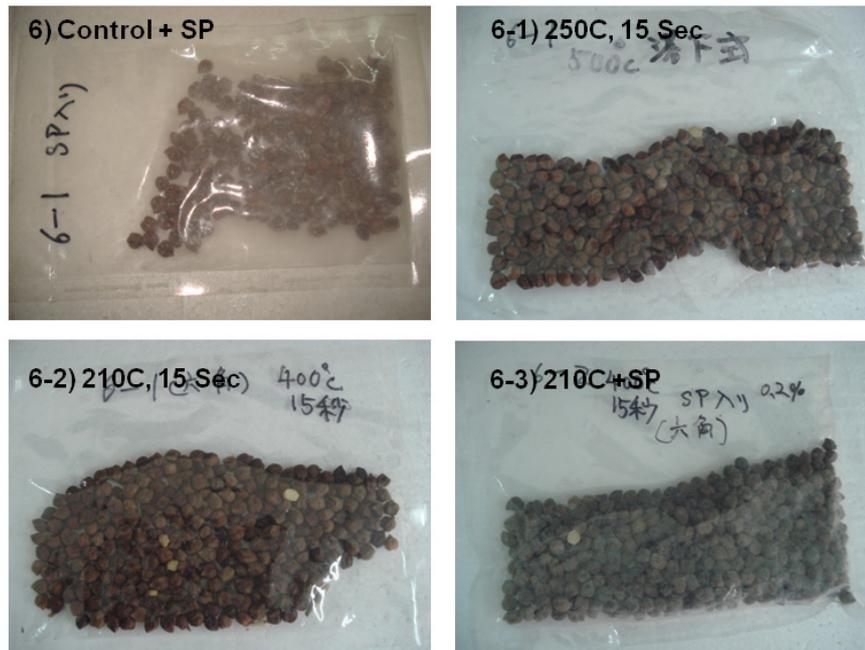


Figure 6: 6) Control; 6-1) USST Treatment at 250 °C; and 6-2) USST Treatment at 210°C; and 6-3) USST treatment at 210 °C followed by mixture with SP powder (0.1%). The treated and non-treated chickpea samples were kept at room temperature for > 26 months.

however, optimization of treatment time and temperature is required for each food product.

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CONFLICTS OF INTEREST

There are no conflicts of interest in the content of the manuscript.

REFERENCES

1. BARC (Bangladesh Agricultural Research Council). Final report on agricultural research priority: vision-2030 and beyond; sub-sector: food availability and consumption, post-harvest losses, agro-processing technology, food safety and human nutrition. *MAQ*. 2010; 14-24.
2. WFP/DFID. Food security in Bangladesh, World Food Programme, Dhaka; 2005.
3. Mujurndar AS, Law CL. Drying technology: trends and applications in postharvest processing. *Food Bioprocess Technol*.

2010; 3: 843-852. doi: [10.1007/s11947-010-0353-1](https://doi.org/10.1007/s11947-010-0353-1)

4. Mujurndar AS. Handbook of industrial drying. 3rd ed. Boca Raton: CRC; 2007.
5. Beeby C, Potter OE. Steam drying. Proc. 4th Int Drying Symp. Kyoto, Japan; 1985.
6. Chu JC, Lane AM, Conklin D. Evaporation of liquids into their superheated vapors. *Industrial Eng. Chem*. 1953; 45: 1586-1591. doi: [10.1021/ie50523a059](https://doi.org/10.1021/ie50523a059)
7. Wimmerstedt R. Steam drying - history and future. *Drying Technol*. 1995; 13: 1059-1079.
8. Topin F, Adrist LT. Analysis of transport phenomena during the convective drying III superheated steam. *Drying Technol*. 1997; 15: 2239-2261.
9. Ezhil E. Superheated steam drying of food-a review. *World Journal of Dairy and Food Sciences*. 2010; 5 (2): 214-217.
10. Sawai J, Satoh M, Horikawa M, Shiga H, Kojima H. Heated scallop-shell powder slurry treatment of shredded cabbage. *J. Food Prot*. 2001; 64: 1579-1583.
11. USDA. National database protein and calories in nuts. Available at <http://ndb.nal.usda.gov/> 2011; Accessed March 14, 2012.
12. Hirano S, Shima T, Shimada T. Proportion of aflatoxin B1

contaminated kernels and its concentration in imported peanut samples. *Shokuhin Eiseigaku Zasshi*. 2001; 42(4): 237-242.

13. David M. In the Russian steppes: the introduction of Russian wheat on the great plains of the United States. *Journal of Global History*. 2008; 3: 203-225. doi: [10.1017/S1740022808002611](https://doi.org/10.1017/S1740022808002611)

14. Liu Q, Qiu Y, Beta T. Comparison of antioxidant activities of different colored wheat grains and analysis of phenolic compounds. *J. Agric. Food Chem.* 2010; 58(16): 9235-9241. doi: [10.1021/jf101700s](https://doi.org/10.1021/jf101700s)

15. Gautam P, Dill-Macky R. Impact of moisture, host genetics and *Fusarium graminearum* isolates on *Fusarium* head blight development and trichothecene accumulation in spring wheat. *Mycotoxin Research*. 2012; 28(1): 45-58. doi: [10.1007/s12550-011-0115-6](https://doi.org/10.1007/s12550-011-0115-6)

16. George M, Nzioki HS. Aflatoxin prevalence data collection. Working paper 1, August 2010, *International Food Policy Research Institute*. Available at http://www.ifpri.org/sites/default/files/publications/aflacontrol_wp01.pdf 2010; Accessed on March 14, 2012.

17. Butcher GD, Miles RD. Minimizing microbial contamination in feed mills producing poultry feed. a series of the veterinary medicine-large animal clinical sciences department, institute of food and agricultural sciences, university of Florida. Original publication date May, 1995. Reviewed March 2011. Available at <http://edis.ifas.ufl.edu> 1995; Accessed on March 14, 2012.

18. Daniel Z, Maria H. Domestication of plants in the old world. 3rd ed. Oxford University Press; 2000: 110.

19. Chickpea. Website: <http://crnindia.com/> Available at: <http://www.crnindia.com/commodity/chickpea.html> 1998; Accessed 2015.

20. Rahman MM, Khan SI. Food security in Bangladesh: Food Availability, GoB/UN WFP, Dhaka; 2005.

21. Pittaway JK, Robertson IK, Ball MJ. Chickpeas may influence fatty acid and fiber intake in an ad libitum diet, leading to small improvements in serum lipid profile and glycemic control. *Journal of the Am. Dietetic Assoc.* 2008; 108(6): 1009-1013. doi: [10.1016/j.jada.2008.03.009](https://doi.org/10.1016/j.jada.2008.03.009)