

# Hot air-assisted radio frequency heating treatment for controlling Aflatoxin B1 on corn grains

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**Abstract.** The best condition of hot air-assisted RF-heating treatment Aflatoxin B1 decontamination was 19.05% wb of initial grain moisture content with 80 °C for 20 minutes. Additionally, the RF-heating treatment also had the high efficiency on Aflatoxin B1 decontamination when applied under conditions: 80 °C for 20 minutes, and reduce to 69.6%.

## Introduction

Corn is the primary food crop of China both in terms of planting area and total yield production [1], long-term storage of corn grains always accompanies with mold, which would result in significant quality and economic loss. Some of the mold can produce mycotoxin which would not only cause serious quality loss, but also food safety concern [2]. Among the various mycotoxins, aflatoxin B1 (AFB1) is the most potent mutagen, teratogen, which is identified as a Group 1 carcinogen by the International Agency for Research in Cancer (IARC) [3]. The frequent incidence of these toxins in agricultural commodities has a potential negative impact on the economies of the affected region.

Many methods have been studied to control the aflatoxins inside the grain, including chemical, biological and physical method [4-5]. Chemical degradation strategies are effective, such as ammonization [6], influence of acids and bases, influence of oxidizing agents or with various inorganic and organic chemicals [7]. But, they would lead to second contamination in food.

AFB1 can be degraded by many microorganisms, enzymes [8], and the extract of some plants [9], and hence, the biological decontamination of AFB1 appears attractive, but this method may have certain disadvantages in that the organisms would utilize food nutrients for their growth and release undesirable metabolites [10].

Compared with the chemical and biological methods, the physical decontamination of AFB1 seems more promising and some methods, such as solar radiation [11], have gained practical applications. In addition, many other methods, including ozonation [12-15], ionization [16], gamma ray irradiation [17], UV irradiation [18, 19], and pulsed light exposure

[20], have been reported capable of effectively degrading AFB<sub>1</sub> in artificial systems or real foods. Meanwhile, the structures of some physical degradation products have been elucidated by several authors, and their safety was assessed as well by either the AMES test or based on the structure–toxicity relationship [21]. These researches greatly justify the practical application of the physical methods in AFB<sub>1</sub> decontamination.

Radio frequency (RF) heating is a novel thermal treatment method at a frequency range from 3 kHz to 300 MHz. It generates heat inside the food products by friction of molecules dominated by ionic conduction and dipole rotation, thus heating dielectric materials rapidly and volumetrically, and its heating with little quality loss [22].

## **Materials and methods**

### **Materials**

The standard AFB<sub>1</sub> (2, 3, 6a, 9a-tetrahydro-4-methoxycyclopenta [c] furo [2, 3: 4, 5] furo [2,3-h] chromene-1,11-dione; C<sub>17</sub>H<sub>12</sub>O<sub>6</sub>; purity > 98%) was purchased from Sangon Biotech Co., Ltd. (Shanghai, China). Acetonitrile of UPLC grade was obtained from Merck (Merck KGaA, Germany). The standard was dissolved in acetonitrile to make a stock solution of 100 mg/L. Corn grain (aflatoxins < 20 ug/kg) used in this research was purchased from local market in Taian, China. The average initial MC of corn was 10.08 ± 0.2% wet basis (w.b.). To explore the RF heating uniformity in corns with different moisture levels, other samples with MC of 19.05.0%, 22.25% and 25.55% w.b. were prepared for the experiment. The initial samples were conditioned by direct addition of predetermined amount of distilled water to obtain the targeted MC [24]. The preconditioned samples were shaken by hands for 10 min. Then the samples were sealed in hermetic plastic bags and stored at 4 ± 1°C for more than 7 d in a refrigerator (BD/BC-297KMQ, Midea Refrigeration Division, Hefei, China) for equilibrium.

### **Hot air-assisted RF heating system**

The heating process was conducted in a 6 kW, 27.12 MHz pilot-scale free running oscillator RF system (SO 6B, Strayfield International, Wokingham, U.K together with a hot air system supplied by a 6 kW electric heater. The size of the parallel perforated electrode plates was 40 cm × 83 cm, the gap between the top electrode and bottom electrode was adjusted between 130 and 200 mm to regulate coupling of RF energy to the corn samples for obtaining desired heating rate in corns [25-26].

### **AFB<sub>1</sub> contamination**

A acetonitrile stock solution of AFB<sub>1</sub> at a concentration of 100 ug/mL was diluted 25 fold in acetonitrile to produce the working solution. Each preprocessed corn sample (500 g) was placed into a polyethylene bag. Then, 5 mL of the working solution of AFB<sub>1</sub> was sprayed as homogeneously as possible on the feed sample using an atomizer (DeVilbiss Healthcare, Somerset, PA, USA). After drying for 30 min, the contaminated sample thoroughly mixed by hand for 5 min. Thus, 50 ug/kg contamination level of AFB<sub>1</sub> was achieved in the sub-sample. The corn samples of pollution were divided into portions of 100 g in the polyethylene petri dishes and subjected to hot air-assisted RF heating.

### **Corn quality analyses after RF heating treatment**

The method of Kjeldahl following the AOAC standard was used for determining the nitrogen content, and the protein was calculated by the nitrogen content multiplying the conversion factor of 6.25. Fat content in corn was measured by the Soxhlet extraction method following the AOAC method.

## RF treatment

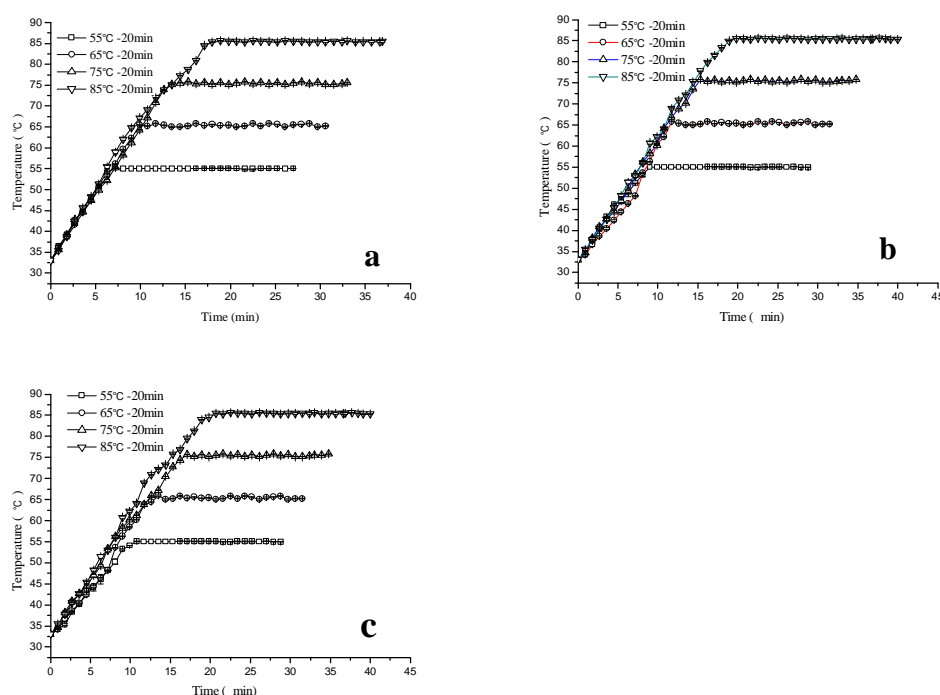
According to the degradation results of aflatoxin B1 in *Perilla frutescens* L. highland oil seed by radio frequency processing [27], 55°C, 65°C, 75°C, and 85°C were selected as target temperatures for RF treatment.

## Statistical analyses

All runs were conducted in triplicate, and the results were expressed as mean  $\pm$  SD of triplicate treatments unless stated otherwise. Analysis of variance (ANOVA;  $p < 0.05$ ) and Duncan's multiple range tests were used to evaluate the differences between the different groups. All analyses including calculations were conducted with the aid of the statistical software SPSS 21.0, and the graphs were created in Origin 8.5.

## Results and discussion

### Hot air-assisted RF heating temperature profiles



**Fig. 1** Temperature profiles of hot air-assisted RF heating for corn with different moisture content of 19.05%, 22.25% and 25.55%, respectively.

The typical temperature profiles for hot air-assisted RF heating of the corn grains are illustrated in Fig. 2. Those temperature profiles were obtained by placing the fiber optic sensor at the cold spot inside the container. During holding, hot air assisted to maintain temperature stable in RF unit. RF energy heated the corn grains rapidly, about 7.2min, 9.9 min, 13.5 min and 18 min for moisture content of 19.05% corn grains, 9 min, 11.7 min, 15.3 min and 19.8 min for moisture content of 22.25% corn grains, and about 10.8 min, 13.5 min, 17.1min and 20.7min for moisture content of 25.55% corn grains to reach 55 °C, 65 °C, 75 °C and 85 °C, respectively. RF heating rate for moisture content of 19.05% corn grains was higher than moisture content of 22.25% and 25.55% corn grains, These observed phenomena were similar to those found by Huang et al [28] and Zhang et al [29], in which the portion with higher moisture content has

larger dielectric loss factor and the larger loss factor caused a decrease in RF heating rates during the dielectric heating process [30]. RF heating rate also affected by many other conditions, such as RF power, electrode gap, sample size and physical, thermal and dielectric properties [31].

### AFB1 Contamination

Table 1 The Aflatoxin B1 contamination of corn grains under various radio frequency heating temperature treatment.

Treatment	Aflatoxin B1 Contamination (ppb)
RF treated temperature(°C)	
55	47.77±0.99d
65	34.58±1.97c
75	22.93±0.78b
85	15.22±0.11a

\* Values with different letters in the same column are significantly different ( $p < 0.05$ ). Results are the means of three determinations  $\pm$  standard deviations.

Table 1 shows Aflatoxin B1 contamination for corn grains with MC of 19.05 under four different temperatures at 55, 65, 75 and 85 °C with holding time of 20 respectively. After air-associated RF heating, with the rising of RF heating temperature, Aflatoxin B1 contamination was decreased significantly ( $p < 0.05$ ). When RF heating temperature increased to 85 °C and with 20 minutes holding, Aflatoxin B1 contamination decreased by 15.22 ug/kg, and was lowest with other treatments. Similar result was observed by Vearasilp et al [27], who reported that after RF heating at 50, 60, 70, 80 and 90 °C for the duration of 10 minutes, there was significant difference ( $P < 0.05$ ).

### Corn sample quality

Table 2 the protein and fat content of corn grains under various radio frequency heating temperature treatment.

Treatment	Protein (%)	Fat (%)
RF treated temperature(°C)		
control	6.55± 0.15b	5.62 ± 0.07a
55	6.52 ± 0.04b	5.60 ± 0.03a
65	6.38 ± 0.06ab	5.61± 0.05a
75	6.35 ± 0.04ab	5.57 ± 0.13ab
85	6.32 ±0.05ab	5.56 ± 0.21ab

\* Values with different letters in the same column are significantly different ( $p < 0.05$ ). Results are the means of three determinations  $\pm$  standard deviations.

The changes of protein and fat of corn samples before and after RF heating 55, 65, 75 and 85 °C with 20 minutes holding treatment are shown in Table 2. The results shows that the mean protein and fat values both for control and RF heating temperature 55, 65, 75 and 85 °C treated corn samples. As the heating temperature increases, the protein and fat were constantly decreases. The RF treatment resulted in an approximate 0.23% and 0.06% decrease in protein and fat, but there was no significant difference ( $P > 0.05$ ) between control and RF treated samples. Similar phenomena were found in RF treated milled rice [32-34].

### Conclusions

In this work, the degradation of AFB1 by hot air-assisted RF heating was studied by

degradation efficiency determination, AFB1 could be effectively degraded by hot air-assisted RF heating, and holding time of 20 min achieved 34.78 ug/kg reductions in 19.05% MC (w.b.) corns after RF heating at 85 °C, and not effect on the quality of corn.

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