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(54) Title: SYSTEM AND METHOD OF TREATING FOOD PRODUCTS

(57) Abstract: A method of treating food products utilizes the sequential application of ozone treatment and infrared (IR) heating. The ozone treatment includes exposing the food product to a gaseous ozone environment for a duration of time. The IR heating includes applying IR irradiation to increase the temperature of the food product.

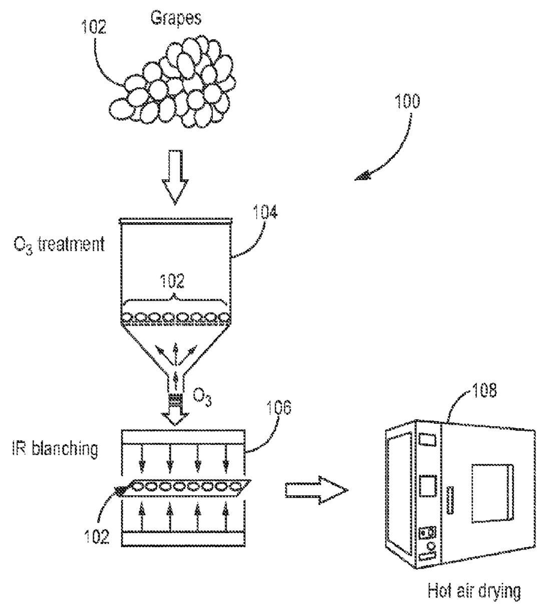

FIG. 1

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SYSTEM AND METHOD OF TREATING FOOD PRODUCTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/050,472, filed July 10, 2020, which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] The present invention is directed generally to processing food products, and in particular to systems and methods of sanitizing and drying food products.

[0003] A number of food products – in particular fruits and vegetables – utilize drying processes. Sulfur dioxide (SO_2) is widely used in fruit drying process for maintaining light product color and ensuring microbial safety. However, if not properly handled SO_2 may cause health problems in humans and may further result in environmental damage if not disposed of properly. Therefore, it would be desirable to identify an alternative to the utilization of SO_2. In addition, it would be beneficial if the alternative provided microbial safety while maintaining the desired light color change associated with SO_2 utilization.

DESCRIPTION OF THE DRAWINGS

[0001] Figure 1 is a block diagram of a sequential ozone treatment and Infrared (IR) heating process according to some embodiments.

[0002] Figure 2 is a block diagram of an ozone treatment apparatus according to some embodiments.

[0003] Figure 3 is a block diagram of an infrared (IR) heating apparatus according to some embodiments.

[0004] Figures 4A and 4B are graphs illustrating the effect of ozone treatment for various time periods and concentration levels on microorganism levels according to some embodiments.

[0005] Figure 5 is a photograph illustrating the color of dried grapes produced using ozone treatment according to some embodiments.

[0006] Figure 6 is a graph illustrating surface temperature and internal temperature of a food product heated using IR heating methods according to some embodiments.

[0007] Figures 7A and 7B are graphs illustrating the effect of IR heating on microorganism levels according to some embodiments.

[0008] Figure 8 is a photograph illustrating the color of dried grapes produced using IR heating for various durations of time according to some embodiments.

[0009] Figure 9 is a chart illustrating the effect of IR heating on PPO activity according to some embodiments.

[0010] Figures 10A and 10B are graphs illustrating the effect of sequential use of ozone treatment and IR heating on microorganism levels according to some embodiments.

[0011] Figure 11 is a photograph illustrating the color of dried grapes produced using sequential application of ozone treatment and IR heating according to some embodiments.

DETAILED DESCIRPTION

[0012] The present invention is directed generally to the treatment of food products. The treatment process utilizes the sequential application of ozone gas to the food product followed by infrared (IR) heating of the food product. The combination of ozone treatment and IR heating acts to sanitize the food products (i.e., reduce the microbial load) while inactivating browning enzymes that cause the browning of food products. In addition, the utilization of IR heating as a pre-treatment method to hot air drying results in a reduction of hot air drying time. In some embodiments, the reduction in hot air drying time is 30% or more. In particular, the sequential use of ozone treatment and IR heating provides a synergetic effect on the reduction of microbial load and product color change during drying process. In addition, it has been found that sequential ozone treatment and IR heating provides functionality commensurate with that of traditional Sulfur dioxide (SO_2) treatment without the corresponding health and environmental concerns associated with SO_2.

[0013] Figure 1 is a block diagram of a sequential ozone treatment and Infrared (IR) heating process 100 according to some embodiments. In the embodiment showing in Figure 1, grapes 102 are utilizes as an exemplary food product to be dried. In other embodiments, other types of fruits and or vegetables may be utilized (e.g., apples, bananas, beans, etc.). In some embodiments, food products may include other food products, such as meats (e.g., fish, chicken). At step 104, the grapes 102 receive ozone (O_3) treatment. As described in more detail with respect to Figure 2, ozone treatment relies on the exposure of the grapes (or other food product) to ozone (O_3). In some embodiments, the ozone in a gaseous state is applied to the grape 102. The concentration of the gaseous ozone applied to the food product may be varied according to the application. For example, in some embodiments the ozone concentration is less than 200 parts-per-million (ppm). In other embodiments, the ozone concentration may be between 200-400 ppm, between 400-600 ppm, between 600-800 ppm, or greater than 800 ppm. In some embodiments, the exposure time of the zone treatment may be varied according to the application. For example, in some embodiments the exposure time of the food product to the ozone treatment is approximately 30 minutes. In some embodiments the exposure time is between 30 minutes and 60 minutes. In some embodiments the exposure time is between 60 minutes and 90 minutes. In some embodiments the exposure time is between 90 minutes and 120 minutes. In some embodiments the exposure time is greater than 120 minutes.

[0014] As described in more detail below, ozone treatment acts to reduce the microbial load of the food product. In some embodiments, the reduction in microbial load caused by the ozone treatment may be a result of oxidation action initiated by the ozone treatment with respect to the glycoproteins and glycolipids of the cell membrane which causes changes to the permeability of the cell, resulting in the leakage of cellular material. In some embodiments, ozone treatment causes the oxidizing of polyunsaturated fatty acid to acid peroxides, which modifies the cellular activities of the treated microbial. In some embodiments, ozone treatment may also act on some sensitive components, such as thymine, cytosine and uracil, causing a decrease in the transcription activity of DNA. The net result though, is an overall reduction in microbial load associated with the food product.

[0015] In some embodiments, the ozone treatment may cause an oxidation of cellular components of amino acids in enzymes. In some embodiments, this results in a reduction of activity of browning enzymes and therefore may result in less color change of the food product. For example, in embodiments in which the food product being dried is grapes, the color lightness of the grapes may be maintained via ozone treatment of the grapes.

[0016] At step 106 the ozone treated food product (e.g., grapes, in the embodiment shown in Figure 1) are heated using infrared (IR) heating. Heating times and temperatures may be varied according to the application. For example, in some embodiments heating times may be between approximately one and five minutes. In other embodiments, heating times may be increased as necessary. In addition, heating intensity may be varied according to application. In some embodiments, the IR emitter (shown in more detail in Figure 4) is located at a known distance (e.g., 15 cm) from the food product and operates at a known radiation intensity (e.g., 4685 W/m^2). In other embodiments, the IR radiation intensity may be higher or lower – for example, between 3,500-6,000 W/m^2. Both the distance to the food product and the radiation intensity may be varied depending on the application. In some embodiments, IR heating is controlled to heat the food product to a desired temperature. In some embodiments the heating is controlled based on monitored surface temperatures of the food product (e.g., grapes). For example, in some embodiments the duration and intensity of IR heating is selected to increase the surface temperature of the food product to a desired temperature. In some embodiments the IR heating process ends when the threshold temperature is reached. In some embodiments, the IR heating process maintains the food product at the desired temperature for a duration of time. In some embodiments, the surface temperature is heated to a temperature equal to or greater than 60° Celsius (C); in some embodiments equal to or greater than 70°C; in some embodiments equal to or greater than 80°C and in some embodiments equal to or greater than 90°C. In some embodiments, the duration and intensity of IR heating is selected to increase the interior temperature of the food product to threshold temperature. Once again, in some embodiments IR heating continues until the threshold internal temperature is reach, while in other embodiments the IR heating continues for a duration of time after the internal threshold temperature is reach. In some embodiments, the threshold internal temperature is greater than or equal to 50°C; in some embodiments the internal temperature is greater than or equal to 60°C, in some embodiments the internal temperature is greater than or equal to 70°C, and in some embodiments the internal temperature is greater than or equal to 80°C.

[0017] As described in more detail below, IR heating at step 106 causes a reduction in microbial load of the food product. In some embodiments, IR heating acts to thermally inactivate the microorganisms by damaging DNA, RNA, ribosome, cytoplasm, cell envelope, and protein in the microorganisms located on the food product (e.g., grapes). In addition, IR heating causes an inactivation of browning enzymes

[0018] At step 108 the ozone-treated and IR-heated food product is further processed. For example, in the embodiment shown in Figure 1, processing at step 108 includes additional drying of the food product utilizing a hot air drying method to dehydrate the food product. For example, in the example illustrated the grapes 102 are dehydrated to produce raisins. The sequential application of ozone treatment followed by IR heating provides several unexpected benefits. As discussed in more detail with respect to the results of experiments conducted, the sequential application of ozone treatment and IR heating provides a synergistic effect on both reduction of microbial loads and deactivation of browning enzymes responsible for browning of certain food products (e.g., grapes, apples, fish, etc.). In particular, the reduction in microbial load utilizing the sequential application of ozone treatment and IR heating is greater than the reduction achieved with either ozone-only treatment and IR heating-only treatment. In some embodiments (described in more detail below), the sequential application of ozone treatment and IR heating provided a 4-5 log reduction of microbial load, which is greater than the microbial load reduction achievable via ozone-only treatment or IR-only heating. Furthermore, the sequential application of ozone treatment and IR heating reduced browning of the food product as compared with food product that received ozone-only treatment and food product that received IR heating-only treatment prior to drying. Finally, the sequential application of ozone-treatment following by IR heating reduced the drying time required for the food product. In some embodiments, the drying time (utilizing a hot air drying method described with respect to step 108) was reduced by over 33% when utilizing the sequential application of ozone treatment and IR heating of the food products.

[0019] Figure 2 is a block diagram of an ozone treatment apparatus 200 according to some embodiments. In some embodiments, ozone treatment apparatus 200 includes an air cylinder 202, ozone generator 204, ozone chamber 206, and ozone analyzer 208. In some embodiments, ambient air may be provided to ozone generator 204. However, in the embodiment shown in Figure 2, dry air (i.e., low-humidity) stored by air cylinder 202 is provided to ozone generator 204. In response, ozone generator 204 generates ozone (O_3) that is provided in a gaseous state to ozone chamber 206. In some embodiments, ozone analyzer 208 and associated sensor 210 is utilized to monitor the concentration of ozone (O_3) within the ozone chamber 206 and provides feedback to ozone generator 204 to either increase or decrease the flow of ozone into the ozone chamber 206. In some embodiments, the food product is placed within the ozone chamber 206 on a tray. In some embodiments the food product is arranged in a single layer that allows exposure of the food product to the ozone environment. As described in more detail below, the ozone concentration and duration of exposure may be modified depending on the application.

[0020] Figure 3 is a block diagram of an infrared (IR) heating apparatus 300 according to some embodiments. In the embodiment shown in Figure 3, the IR heating apparatus 300 includes IR heating chamber 302. In some embodiments, IR heating chamber 302 is single-sided or double-sided. The embodiment shown in Figure 3 illustrates double-sided heating, in which the food product (i.e., sample 303) is placed within the chamber 302 and is irradiated from both sides. In other embodiments, single-sided IR irradiation may be utilized. In some embodiments, a temperature measuring device 306 is utilized to monitor the temperature within the IR heating chamber 302. In some embodiments, temperature measuring device 306 monitors temperature within the IR heating chamber 302. In some embodiments, temperature measuring device 306 monitors the surface temperature of the food product or sample being heated. In some embodiments, temperatures measuring device 306 monitors the internal temperature of the food product or sample being heated. In some embodiments, temperature measuring device 306 may monitor a combination of chamber temperature, surface temperature, and/or internal temperature of the food product. Feedback from the temperature measuring device 306 is provided to data acquisition device 308, which may be utilized to control (i.e., increase or decrease) the IR irradiation. For example, in the embodiment shown in Figure 3, data acquisition 308 controls a gas valve 304 to increase or decrease the flow of gas (e.g., natural gas) to the IR heating elements.

[0021] Figure 4a is a graph illustrating microorganism population as a result of various concentrations of ozone treatment and various durations of ozone treatment according to some embodiments; and Figure 4b is a graph illustrating the reduction in microorganism population as a result of various concentrations of ozone treatment and various durations of ozone treatment according to some embodiments. Figure 5 illustrates the effect of ozone concentration on the color change of grapes according to some embodiments. The results illustrated in Figures 4a-4b and 5 were obtained by first inoculating grape samples with E. faecium NRRL-B2354 to initial concentration of 10^7 CFU/g to provide the samples with a known microbial load.

[0022] As shown in Figures 4a and 4b, ozone concentrations ranging from 200 ppm to 800 ppm and treatment durations ranging from 30 min to 120 min were tested to determine microorganism reduction and color change of grape. The samples were spread as single layer in a stainless-steel basket and treated with ozone under aforementioned concentrations and treatment times. The effect of each treatment condition on the microbial load reduction was evaluated right after each ozone treatment. After ozone treatment, the treated grapes were dried using hot air at 60°C to a finial moisture content of 10±1% (wet basis). Then the color indices (L, a, b) of dried grapes was measured using a color meter. The populations of E. faecium significantly decreased with the increase of ozone concentration and exposure time. The ozone treatments at 200, 400, 600, and 800 ppm for 120 min achieved 1.96, 2.85, 3.07, and 3.60 log reductions of E. faecium, respectively (Figure 4b). This means that the ozone treatment is effective in reducing microbial loads, but the maximum reduction was less than 4 log.

[0023] In addition, color testing (shown in Figure 5) indicates that ozone treatment acts to at least partially reduce the browning enzyme activity of the samples tested as illustrated visually in Figure 5 and quantitatively in table 1, shown below. In general, ozone treatment resulted in an increase to the L* value and a decrease in the a* value. In particular, when the ozone concentration increased from 200 ppm to 800 ppm, and treatment time from 30 min to 120 min, the L* value increased from 28.78±1.64 to 31.01±1.1, and the a* value decreased from 9.41±1.08 to 8.73±2.00 (Table 1). This indicates that ozone treatment partially reduces the browning enzyme activity and slightly improves the color of dried grapes. In some embodiments, this may be a result of the ability of ozone to oxidize the cellular components of amino acids in enzymes, resulting in reduced activities.

Ozone treatment		Color parameters		
Concentration (ppm)	Time (min)	*L**	*a**	*b**
Control		28.78±1.64abc	9.41±1.08a	9.55±1.65a
200	60	28.00±3.09abc	10.59±2.14a	11.12±4.33a
	120	29.19±3.36abc	10.71±1.53a	9.85±3.20a
400	60	27.09±3.03c	9.37±1.83a	8.25±3.90a
	120	29.65±2.89abc	9.45±4.60a	9.17±4.36a
600	60	27.34±3.15bc	11.68±1.79a	12.44±3.91a
	120	31.73±1.71a	8.99±2.24a	12.11±2.29a
800	60	29.70±2.41abc	9.87±1.41a	11.02±2.78a
	120	31.01±1.16a	8.73±2.00a	11.58±2.59a

TABLE 1

[0024] Figure 5 is a graph illustrating temperature profile of grapes during infrared heating according to some embodiments. In particular, in this experiment, the grape samples were spread as a single layer on a stainless-steel wire mesh placed at distance of 15 cm from the IR emitter and treated under radiation intensity of 4685 W/m^2 for 1, 2, 3, 4, and 5 minutes, respectively. Measured surface temperature is illustrated by line 600 and internal temperature is illustrated by line 602. In this experiment, no ozone treatment was applied to the grapes prior to IR treatment. The center and surface temperatures, color change, and polyphenol oxidase (PPO) enzyme activity were determined. After IR treatment, the samples were dried using a hot air dryer at 60°C. The effect of each IR heating treatment on the microbial load reduction was evaluated after the treatment. The color of IR treated grapes were measured after hot air drying. The obtained results revealed the IR heating increased the temperate of grape in a short time. It took only about 1.3 minute to heat the grape surface to temperature of 90 °C (as shown by line 600), while the center temperature (line 602) reached to 60°C and 70°C after 3.3 and 4.6 min of IR heating. The IR heating for 1, 2, 3, 4, and 5 min reduced the E. faecium population size by 0.26, 0.37, 0.70, 1.02, and 1.58 log CFU/g, respectively (Figure 7B), which were less than 5 log as normally required. As described above, in some embodiments the IR heating thermally inactivated the microorganisms by damaging DNA, RNA, ribosome, cytoplasm, cell envelope, and protein in the treated microorganism.

[0025] In addition, the IR heating produced very light color dried product ($p<0.05$) (Figure 8). After IR heating for 5 min, the L* value of dried grapes was significantly ($p<0.05$) higher than that of the untreated grapes. By increasing the IR heating time from 1 to 5 min, the L* value increased from 29.2±2.2 to 37.3±1.9, while the L* value of untreated grapes was 27.7±3.6 (Table 2). The a* values of dried grapes were much lower than those of the untreated samples. After 5 min of IR heating, the a* value of treated grapes was 2.9±0.5, while the a* value of untreated grapes was 7.9±2.8 (Table 2). This might be attributed to the effective thermal inactivation of browning enzymes (polyphenol oxidase (PPO) and peroxidase (POD)) caused by IR heating, which decreased the darkening of grapes. After IR heating for 5 min, the PPO residual activity in the grapes was lower than 10%. This means that a significant thermal inactivation of PPO occurred and most of the PPO activity was destroyed when the center temperature reached to above 60 °C (Figure 9).

Blanching time	Parameters		
(min)	L*	a*	b*
0	27.7±3.6b	7.9±2.8ab	13.8±4.5a
1	29.2±2.2b	9.5±0.5a	14.5±2.1a

2	28.2±4.2b	6.9±1.9ab	14.2±1.4a
3	29.7±3.1b	6.5±1.0ab	16.3±2.9a
4	33.7±2.4ab	5.2±1.0bc	18.1±2.2a
5	37.3±1.9a	2.9±0.5c	17.3±2.3a

TABLE 2

[0026] The obtained results clearly revealed that IR heating resulted in a powerful inactivation of microorganisms and the browning enzymes, and significantly enhance the lightness of the treated product. However, the IR heating alone could not achieve the 5 log reduction and very light color of dried products.

[0027] Figures 10a, 10b, 11, and 12 illustrate the results of experiments that utilized sequential treatments of food products utilizing ozone treatment and IR heating. Experimental results of the sequential utilization of ozone treatment and IR heating with the use of ozone treatment only and IR heating only.

[0028] In the experiments conducted, the food product (e.g., grapes) were treated with ozone under different gaseous ozone concentrations ranging from 200 to 800 ppm for durations of time ranging from 60 and 120 min, respectively. After ozone treatment, the samples were heated using infrared (IR) for 5 min. After sequential ozone treatment and IR heating, the samples were dried using hot air drying at 60 °C to a final moisture content of 10±1.0% (w.b). The drying time was recorded and compared with that of untreated samples. The microbial load was evaluated right after sequential ozone and IR heating treatment. The color of the dried grapes was measured after hot air drying. The combination of ozone treatment at 800 ppm for 60 and 120 min with IR heating for 5 min reduced the E. faecium by 4.5 and 5.18 log CFU/g, respectively (Figure 10B). Additionally, the sequential ozone and IR heating treatment significantly brightened the color of dried grapes. The values of L* as an indicator of brightness increased from 36.54±3.74 to 41.49±3.69 by increasing the zone concentration from 200 to 800 ppm and treatment time from 60 min to 120 min, respectively, (Table 3, below). The results indicate the sequential ozone treatment and IR heating was able to effectively inactivate the browning enzymes and produce dried grape with light color (Figure 11). It took 48 hr for the hot air drying to dry the slices treated with sequential ozone treatment at 800 ppm for 120 min and IR heating for 5 min, while the corresponding hot air drying for untreated samples was 72 hr. This indicates that the use of IR heating reduced the hot air drying time by 33%.

Treatment		Parameters		
Ozone concentration (ppm)	Exposure time (min)	*L**	*a**	*b**
Control		36.99±1.09b	8.78±0.82a	17.51±1.75b
200	60	36.54±3.74b	8.95±1.11a	16.85±2.76b
	120	40.28±2.61ab	9.30±1.23a	22.33±2.61a
400	60	38.71±1.15ab	8.82±1.72a	20.36±2.66ab
	120	39.48±1.61ab	9.46±2.41a	20.32±4.04ab
600	60	42.36±3.19a	9.85±1.12a	24.15±3.56a
	120	40.47±3.57ab	9.24±1.36a	21.68±2.76ab
800	60	41.38±2.36a	8.38±1.21a	21.21±3.03ab
	120	41.49±3.69a	9.92±0.82a	23.75±3.48a

TABLE 3

[0029] Based on the discovered findings, the embodiments of the present technology of using sequential ozone and IR heating treatment as a pre-treatment method of hot air drying provide the following alternative variants to the previous arts. Ozone treatment has high antimicrobial capacity and can effectively destroy microorganisms and slightly improve the color of treated product by reducing the activities of enzymes causing browning. IR has high heating rate and powerful thermal inactivation capability of microorganisms and the enzymes causing browning and significantly enhances the lightness of the treated product and reduces the drying time for the hot air drying. Separate ozone treatment or IR heating alone cannot achieve 4 to 5 log reduction of microbial load and cannot produce the dried products with very light color. The sequential ozone and IR heating treatment as a pre-treatment method of hot air had positive synergetic effect on reduction of microbial load and product color change during drying process. It can achieve more than 5 log reduction of microbial load that ensured food safety, and produce the dried products with very light color, the new processing method also can reduce the drying time of hot air drying. Sequential ozone treatment and IR heating can achieve similar functions of Sulfur dioxide (SO_2) treatment in fruit drying process and produce dried fruits with ensured safety and light color without any health and environmental concerns.

<u>Discussion of Possible Embodiments</u>

[0030] The following are non-exclusive descriptions of possible embodiments of the present invention.

[0031] A method of treating food products includes applying an ozone treatment to the food product, wherein the ozone treatment includes exposing the food product to a gaseous ozone environment. The method further includes applying infrared (IR) heating to the ozone treated food product.

[0032] The method of the preceding paragraph can optionally include, additionally and/or alternatively any, one or more of the following features, configurations and/or additional components.

[0033] For example, the method may include drying the food product following infrared heating utilizing a hot air dryer, wherein IR heating of the ozone treated food product reduces the drying time of the food product.

[0034] The method may further include wherein the gaseous ozone environment has an ozone concentration greater than 200 parts per million (ppm).

[0035] The method may further include wherein the gaseous ozone environment has an ozone concentration greater than 400 ppm.

[0036] The method may further include wherein the gaseous ozone environment has an ozone concentration greater than 600 ppm.

[0037] The method may further include wherein the gaseous ozone environment has an ozone concentration greater than 800 ppm.

[0038] The method may further include wherein the ozone treatment is applied for a duration of at least 30 minutes.

[0039] The method may further include wherein the ozone treatment is applied for a duration of at least 60 minutes.

[0040] The method may further include wherein the ozone treatment is applied for a duration of at least 90 minutes.

[0041] The method may further include wherein the ozone treatment is applied for a duration of at least 120 minutes.

[0042] The method may further include wherein the IR heating is applied for a duration of at least one minute.

[0043] The method may further include wherein the IR heating is applied for a duration of at least two minutes.

[0044] The method may further include wherein the IR heating is applied for a duration of at least three minutes.

[0045] The method may further include wherein the IR heating is applied for a duration of at least four minutes.

[0046] The method may further include wherein the IR heating is applied for a duration of at least five minutes.

[0047] The method may further include wherein the IR heating includes heating an internal temperature of the food product to a temperature of greater than 50° Celsius (C).

[0048] The method may further include wherein the IR heating includes heating an internal temperature of the food product to a temperature of greater than 60° Celsius (C).

[0049] The method may further include wherein the IR heating includes heating an internal temperature of the food product to a temperature of greater than 70° Celsius (C).

[0050] According to another aspect, a food processing apparatus may include an ozone treatment apparatus including an ozone chamber for exposing a food product to a gaseous ozone environment and an infrared (IR) heating apparatus including infrared heating elements for heating the ozone treated food product.

[0051] The food processing apparatus of the preceding paragraph can optionally include, additionally and/or alternatively any, one or more of the following features, configurations and/or additional components.

[0052] For example, the apparatus may further include a hot air drying apparatus configured to dry the ozone treated and IR heated food product.

[0053] In some embodiments, the ozone treatment apparatus may include an ozone analyzer that measures ozone concentrations in the ozone chamber.

[0054] In some embodiments, the IR heating element includes a temperature monitoring device that measures one of IR heating apparatus air temperature, food product surface temperature, and/or interior temperature of the food product.

CLAIMS

1. A method of treating food products, the method comprising:
applying an ozone treatment to the food product, wherein the ozone treatment includes exposing the food product to a gaseous ozone environment; and
applying infrared (IR) heating to the ozone treated food product.

2. The method of claim 1, further including:
drying the food product following infrared heating utilizing a hot air dryer, wherein IR heating of the ozone treated food product reduces the drying time of the food product.

3. The method of any preceding claim, wherein the gaseous ozone environment has an ozone concentration greater than 200 parts per million (ppm).

4. The method of any preceding claim, wherein the gaseous ozone environment has an ozone concentration greater than 400 ppm.

5. The method of any preceding claim, wherein the gaseous ozone environment has an ozone concentration greater than 600 ppm.

6. The method of any preceding claim, wherein the gaseous ozone environment has an ozone concentration greater than 800 ppm.

7. The method of any preceding claim, wherein the ozone treatment is applied for a duration of at least 30 minutes.

8. The method of any preceding claim, wherein the ozone treatment is applied for a duration of at least 60 minutes.

9. The method of any preceding claim, wherein the ozone treatment is applied for a duration of at least 90 minutes.

10. The method of any preceding claim, wherein the ozone treatment is applied for a duration of at least 120 minutes.

11. The method of any preceding claim, wherein the IR heating is applied for a duration of at least one minute.

12. The method of any preceding claim, wherein the IR heating is applied for a duration of at least two minutes.

13. The method of any preceding claim, wherein the IR heating is applied for a duration of at least three minutes.

14. The method of any preceding claim, wherein the IR heating is applied for a duration of at least four minutes.

15. The method of any preceding claim, wherein the IR heating is applied for a duration of at least five minutes.

16. The method of any preceding claim, wherein the IR heating includes heating an internal temperature of the food product to a temperature of greater than 50° Celsius (C).

17. The method of any preceding claim, wherein the IR heating includes heating an internal temperature of the food product to a temperature of greater than 60° Celsius (C).

18. The method of any preceding claim, wherein the IR heating includes heating an internal temperature of the food product to a temperature of greater than 70° Celsius (C).

19. A food processing apparatus comprising:

an ozone treatment apparatus including an ozone chamber for exposing a food product to a gaseous ozone environment; and an infrared (IR) heating apparatus including infrared heating elements for heating the ozone treated food product.

20. The food processing apparatus of claim 19, further including:

a hot air drying apparatus configured to dry the ozone treated and IR heated food product.

21. The food drying apparatus of claim 19, wherein the ozone treatment apparatus includes an ozone analyzer that measures ozone concentrations in the ozone chamber.

22. The food processing apparatus of claim 19, wherein the IR heating element includes a temperature monitoring device that measures one of IR heating apparatus air temperature, food product surface temperature, and/or interior temperature of the food product.

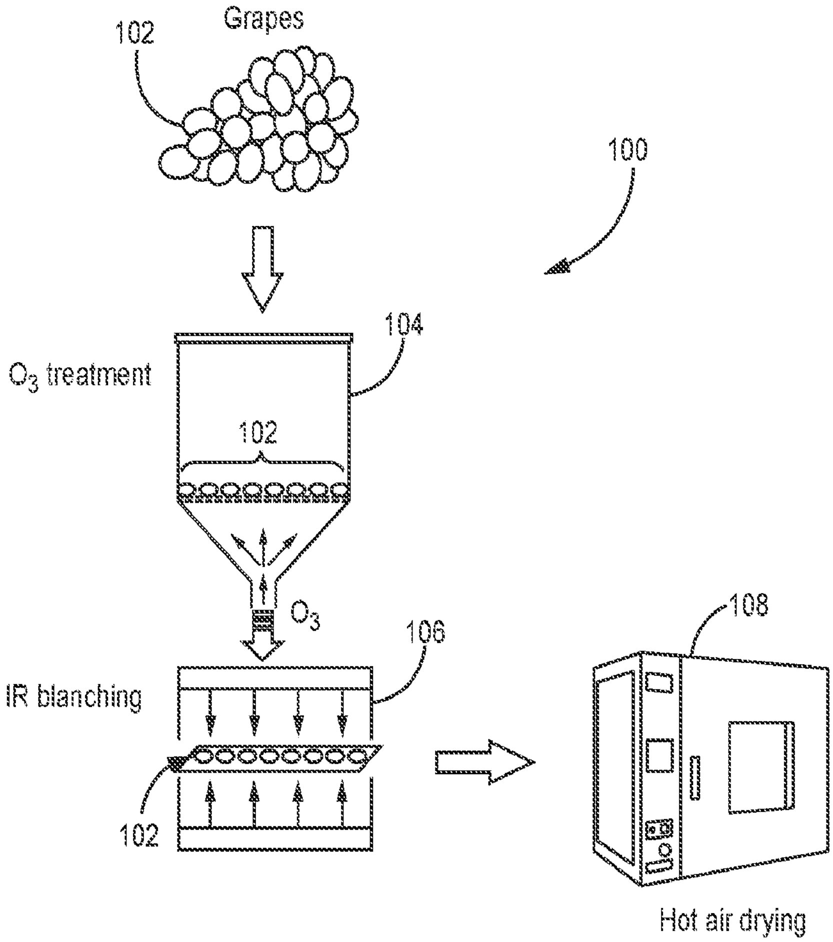
Grapes
102
100
104
O_3 treatment
102
O_3
106
IR blanching
102
108
Hot air drying

FIG. 1

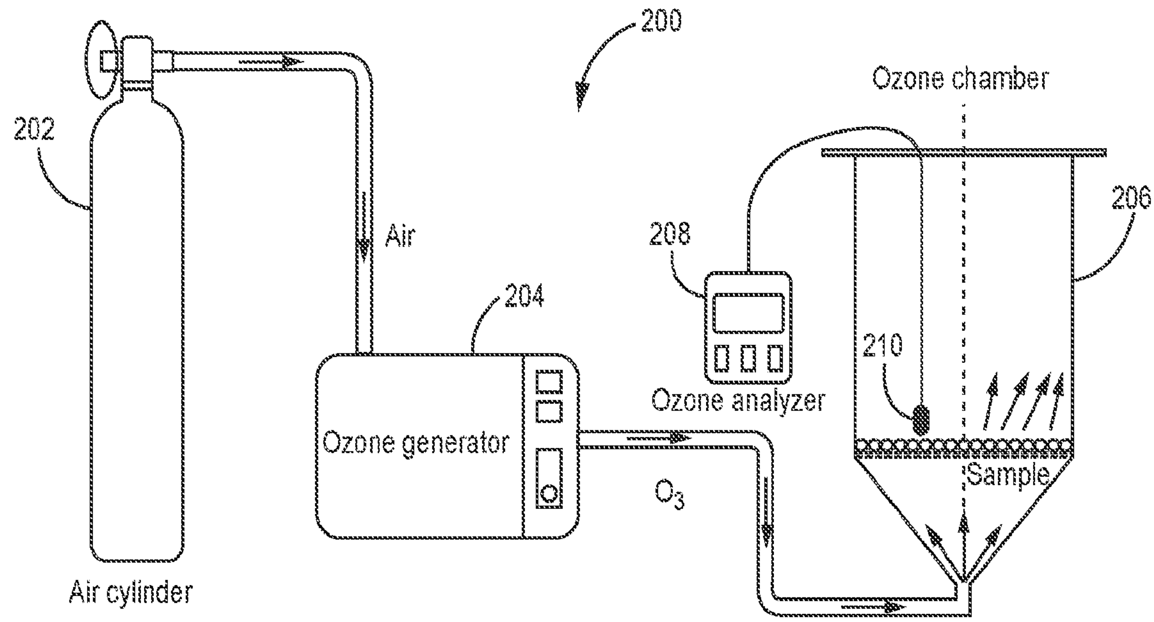
200
Ozone chamber
202
206
Air
208
204
210
Ozone analyzer
Ozone generator
Sample
O_3
Air cylinder

FIG. 2

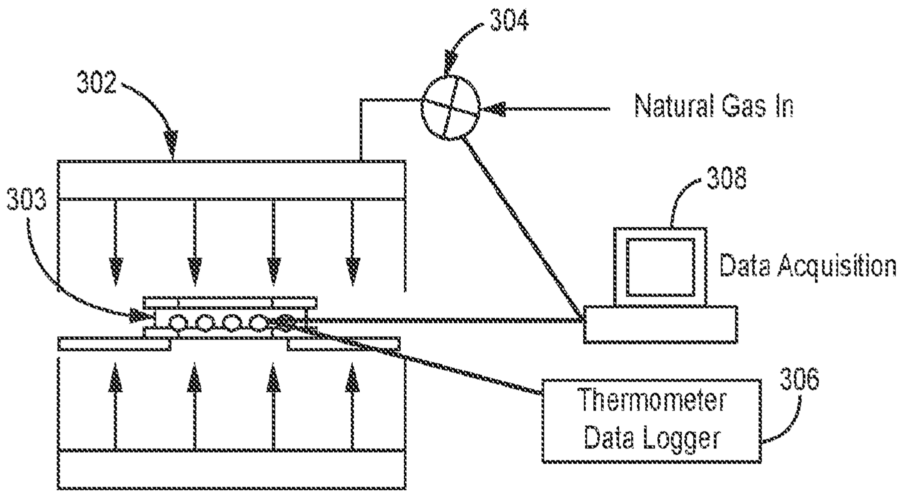
304
302
Natural Gas In
308
303
Data Acquisition
306
Thermometer
Data Logger

FIG. 3

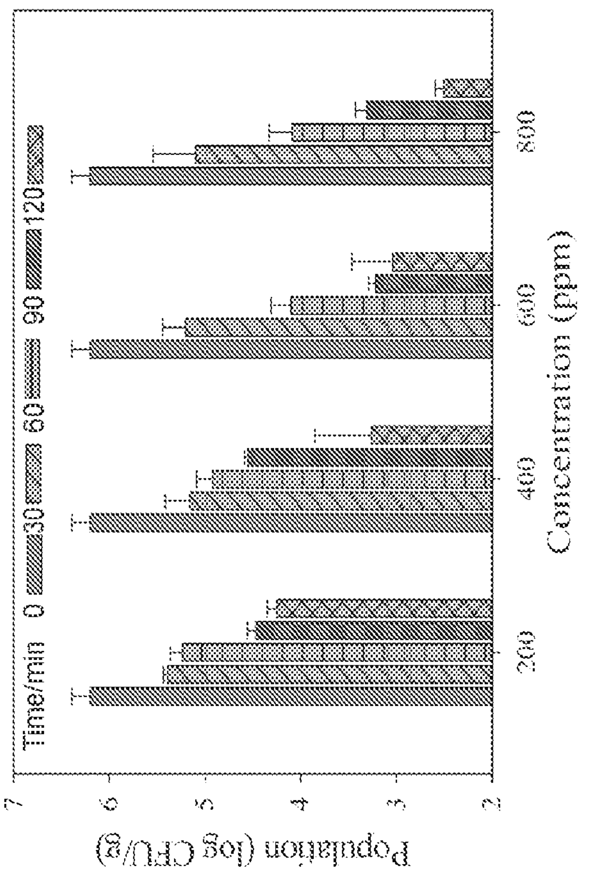

FIG. 4A

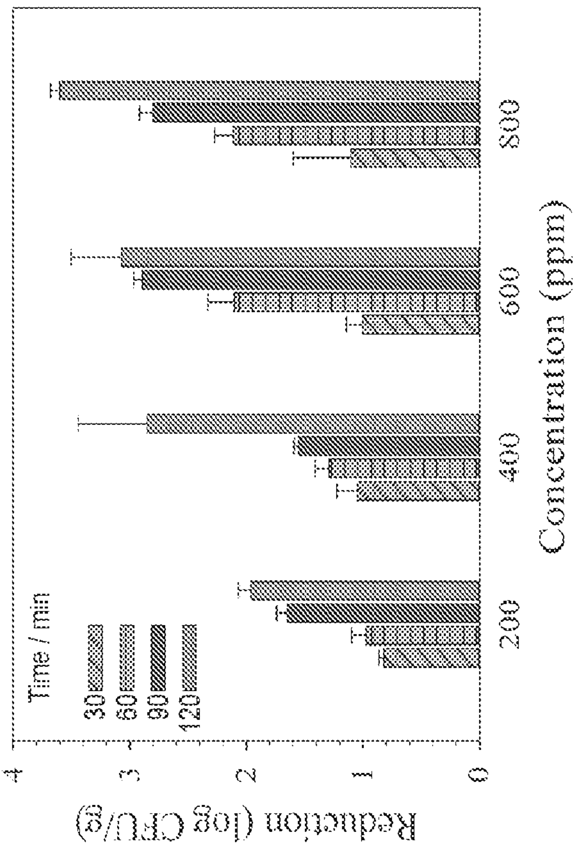

FIG. 4B

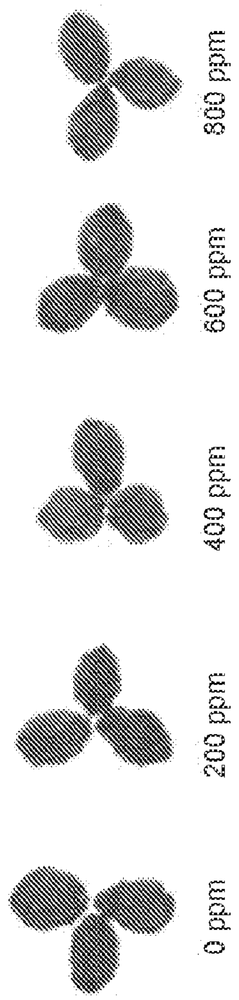

FIG. 5

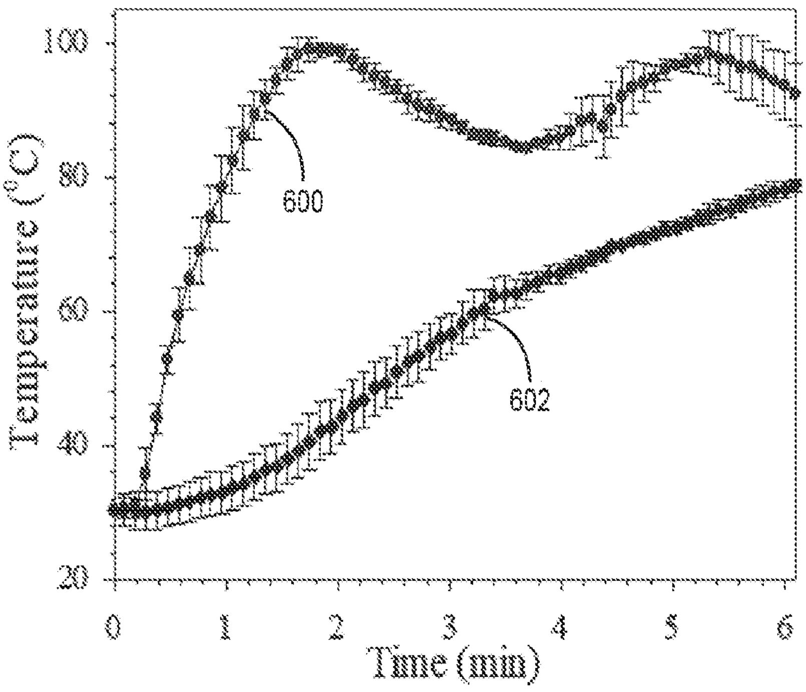

FIG. 6

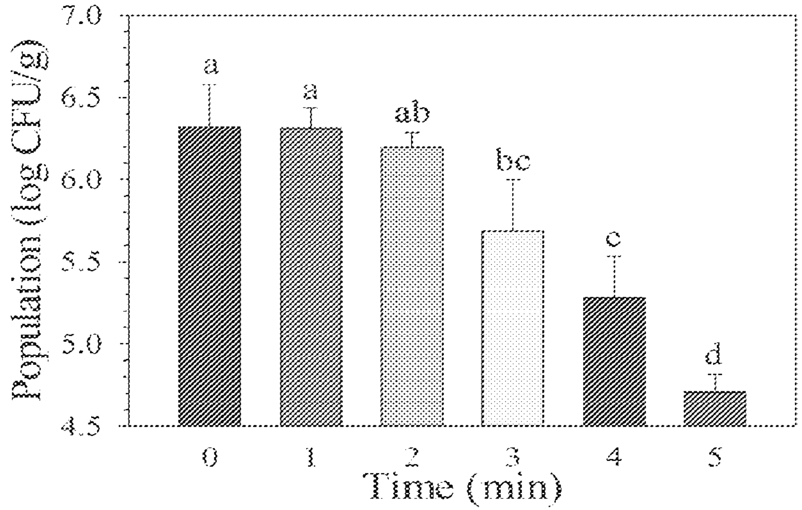

FIG. 7A

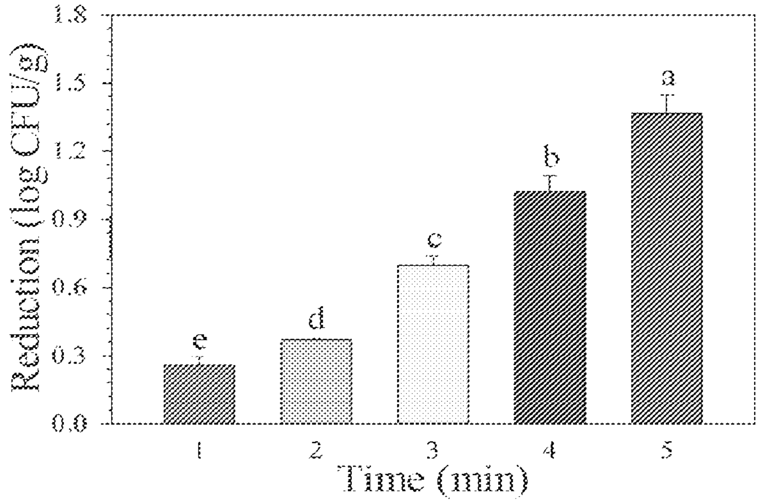

FIG. 7B

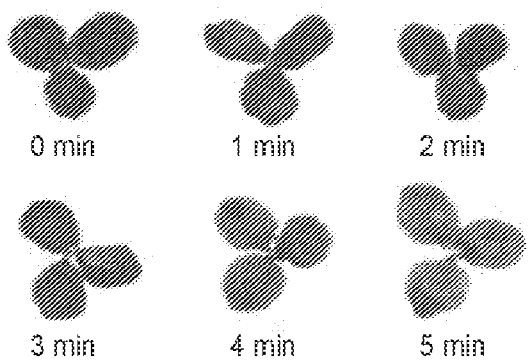

FIG. 8

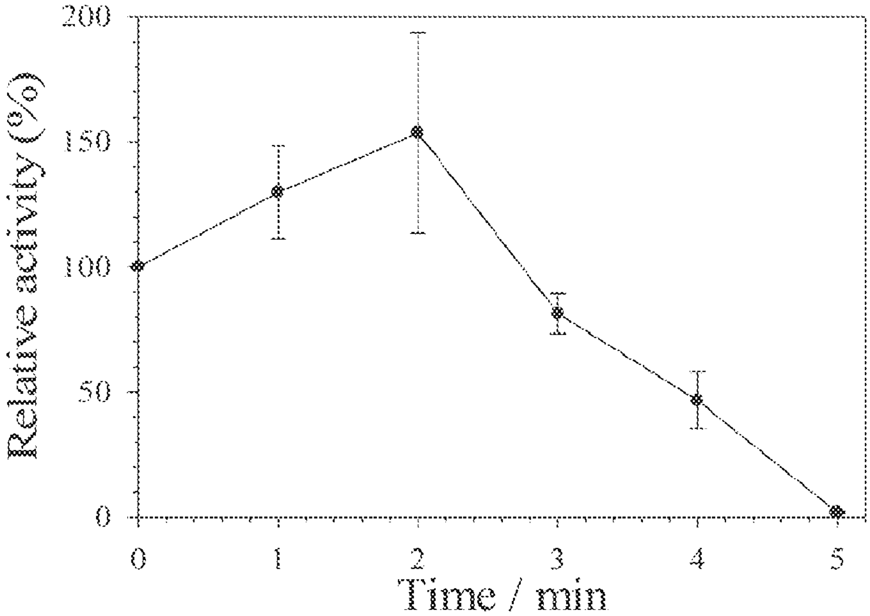

FIG. 9

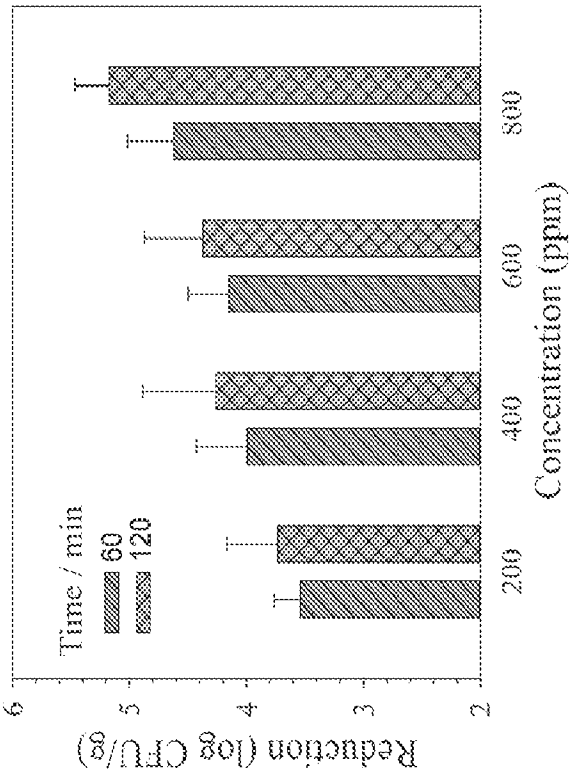

FIG. 10B

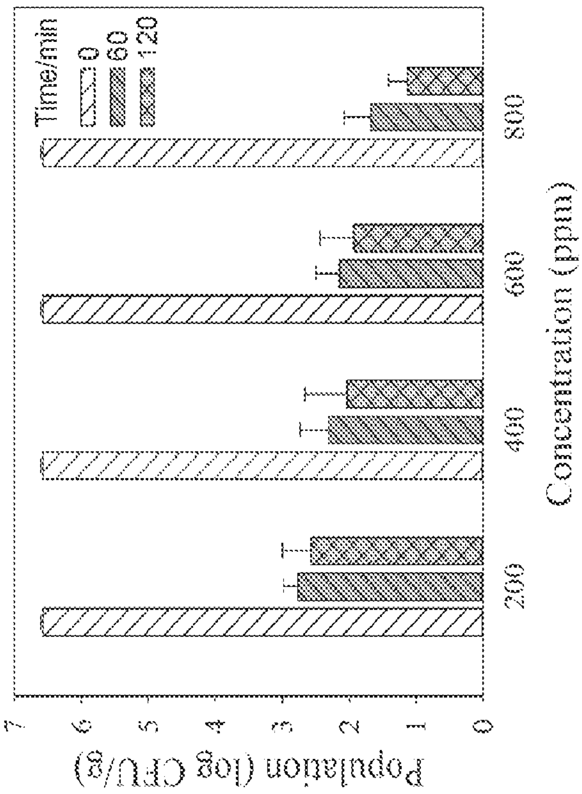

FIG. 10A

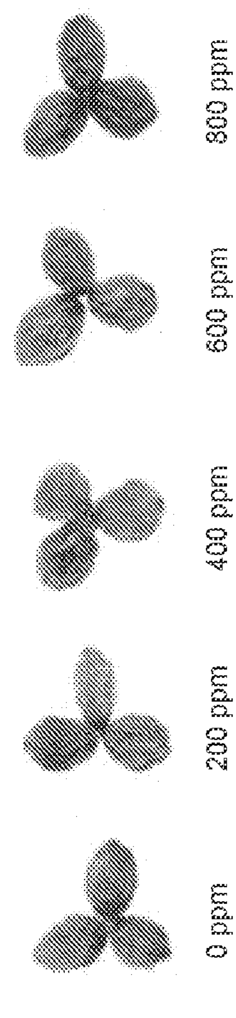

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/41291

A. CLASSIFICATION OF SUBJECT MATTER
IPC - A23L 3/00 (2021.01)

CPC - A23L 3/00; A23L 3/02; A23L 3/358; B65B 25/001

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ------- Y	Watson et al. "Decontamination of chilli flakes in a fluidized bed using combined technologies: Infrared, UV and ozone" (Innovative Food Science and Emerging Technologies) (Available online 24 October 2019) Retrieved from the internet September 17, 2021. url<https://reader.elsevier.com/reader/sd/pii/S146685641930428X?token=5FDDBF34BCC3A73103B7E8E402A07EECBAC14DD0015D51B4959F7140F0E77C2500C4984C177DAC483598F9D1E0FEC54C&originRegion=us-east-1&originCreation=20210919040210>. Entire document, especially Fig. 1:, sample chamber in blue box, ozone generator and IR lamp; abstract, pg 2, col 1 para 2-3; pg 2, col 2, para 2-4; pg 3, col 1, para 3; pg 4, col 1, para 5-6	1, 3/1, 19, 21 and 22 --------------------------- 2, 3/2 and 20
Y	US 2016/0044940 A1 (BUHLER AG) 18 February 2016 (18.02.2016). Entire document, especially para [0048]	2, 3/2 and 20
A	US 4,331,692 A (Drevici, et al.) 25 May 1982 (25.05.1982). Entire document	1-3 and 19-22
A	US 5,405,631 A (Rosenthal) 11 April 1995 (11.04.1995) Entire doecument	1-3 and 19-22
A	US 2,953,429 A (Shiffler) 20 September 1960 (20.09.1960). Entire document.	1-3 and 19-22
A	US 4,549,477 A (McCabe) 29 October 1985 (29.10.1985) Entire document.	1-3 and 19-22

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 September 2021	OCT 20 2021
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/41291

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-18
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.