Garlic varieties and drying methods affected the physical properties, bioactive compounds and antioxidant capacity of dried garlic powder

Hao Gong\textsuperscript{a}, Tao Wang\textsuperscript{b}, Yu Hua\textsuperscript{a}, Wei-Dong Wang\textsuperscript{b}, Cong Shi\textsuperscript{a}, Hai-Xu Xu\textsuperscript{a}, Lu-Lu Li\textsuperscript{a}, Dan-Ping Zhang\textsuperscript{a}, Yue-E Sun and Nan-Nan Yu\textsuperscript{a}

\textsuperscript{a}College of Food Engineering, Xuzhou University of Technology, Xuzhou, China; \textsuperscript{b}Department of Chemistry Engineering, Xuzhou College of Industrial Technology, Xuzhou, China

\section*{ABSTRACT}
This work aimed to determine the effect of freeze drying (FD), hot air drying (HD), vacuum drying (VD), and infrared hot air drying (IRD) on the quality of two key kinds of garlic varieties (white and purple garlic). The quality including colors, bioactive compounds, and antioxidant capacities of dried garlic slices were investigated. The highest whiteness of dried white and purple garlic was found in FD treatments with its values at 87.04 and 81.89, respectively. The higher active substances contents and antioxidant capacities was found in dried purple garlic slices compared to the white ones under the same drying methods. The allicin contents in FD and IRD treated purple garlic were 2.60 and 2.67 mg/g and the total phenolic in these two samples were 5.93 and 4.33 mg/g. Meanwhile, the highest DPPH, ABTS and FRAP (6.64, 2.85 and 5.70 mmol TE/g. DW) was found in the IRD treated purple samples. Principal component analysis revealed the highest allicin contents, total phenolic contents, and antioxidant capacities in purple garlic slices compared to the white one in different drying methods. These results suggested that dried purple garlic under IRD treatment is more suitable for drying industrials than white garlic.

\section*{Las variedades de ajo y los métodos de secado afectaron las propiedades físicas, los compuestos bioactivos y la capacidad antioxidante del polvo de ajo seco}

Este trabajo se propuso determinar el efecto que la liofilización (FD), el secado por aire caliente (HD), el secado al vacio (VD) y el secado por aire caliente infrarrojo (IRD) tienen sobre la calidad de dos tipos comunes de ajo (el blanco y el morado). Para ello se investigó la calidad, incluyendo los compuestos bioactivos y las capacidades antioxidantes de rodajas de ajo seco. Tras los tratamientos FD se logró una mayor blanquea de los ajos blancos y morados secos, los cuales generaron valores de 87.04 y 81.89, respectivamente. Asimismo, se constató que, empleando los mismos métodos de secado y comparando las rodajas de ajo blanco con las de ajo morado, estas últimas presentan el mayor contenido de sustancias activas y capacidades antioxidantes. Mediante la FD y el IRD se estableció que el contenido de alicina en el ajo morado tratado es de 2.60 y 2.67 mg/g, mientras que los fenólicos totales en estas dos muestras fueron de 5.93 y 4.33 mg/g. Por otra parte, en las muestras de ajo morado tratadas mediante IRD se encontró el mayor DPPH, ABTS y FRAP (6.64, 2.85 y 5.70 mmol TE/g. DW). El análisis de componentes principales dio cuenta de que, en comparación con el ajo blanco tratado con diferentes métodos de secado, las rodajas de ajo morado presentan mayores contenidos de alicina y fenólicos totales, al tiempo que poseen capacidades antioxidantes superiores. Estos resultados sugieren que el ajo morado secado bajo tratamiento IRD es más adecuado para el secado industrial que el ajo blanco.

\section*{1. Introduction}
Garlic (\textit{Allium sativum} L.) is widely used as a flavoring agent and herbal medicine in human daily life. Garlic has various functions, including anti-tumor, anti-oxidation, improvement of immunity, and prevention and treatment of cardiovascular diseases (Angeles et al., 2016; Fei et al., 2015; Yan et al., 2020). Garlic also contains numerous nutrients and functional compounds, such as sulfides (alllicin), amino acids, polysaccharides, polyphenols, vitamins, and minerals (Hui, 2020; Liu et al., 2020). Various related products include garlic essential oil, aged garlic extract, garlic powder, preserved garlic, black garlic, and pickled garlic products (Kim et al., 2012; Sommer & Sivarungson, 2015). Among these products, dried garlic occupies an important proportion.

Drying can reduce the moisture content of garlic to avoid its germination and microbial infections with deterioration (He et al., 2019). On the other hand, garlic powder can be obtained for the food industry after drying treatments. Various drying techniques are applied to obtain high-quality garlic powder. Thermal and non-thermal drying processes can cause significant changes in the qualities of foodstuffs (Shi et al., 2017; Woddylo et al., 2009; Younis et al., 2018). Thermal processing (hot-air drying (HD) and vacuum drying (VD)) lead to a significant reduction in the content of allicin and total phenolic content (TPC) of garlic (Rahman et al., 2009). Feng et al. reported the highest allicin, and TPC contents and best antioxidant activity were found in the infrared hot air (IRD) and relative...
humidity-dried garlic slices (37%) (Feng et al., 2019). Aware and Thorat (2011) observed that HD and IRD can significantly decrease the alllic and protein contents in garlic. Zhou et al. also revealed that these two compounds (alllic and protein) significantly decreased in the IRD treatment (Zhou et al., 2017). Non-thermal freeze drying (FD) treatment can compensate for these shortcomings, but its time-consuming and high-power consumption leads to increased processing costs (Martins et al., 2016). Therefore, further research is needed on how to obtain high-quality dried garlic.

The quality of garlic is related to its variety, regions, and growth environment (Montaño et al., 2011). In particular, China has two kinds of garlic varieties, the white and purple garlic based on the color of the testa (Liu et al., 2020). Meanwhile, the type of jujube has an important influence on the quality of dried jujube (Angel et al., 2013). Combining effective drying methods based on different garlic varieties is a strategy to obtain high-quality dried garlic. Little information has been obtained about the effect of different drying methods on the quality of white and purple garlic.

This research aimed to explore the quality changes, including physical (shelflife and colors), bioactive compounds (alllic and total phenolics contents), and antioxidant activities (2,2-diphenyl-1-picrylhydrazyl (DPPH), 2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), and ferric reducing antioxidant power (FRAP)), in white and purple garlic after FD, HD, VD, and IRD. Furthermore, principal component analysis (PCA) was used to obtain the difference in quality of the two varieties under different drying conditions.

2. Materials and methods

2.1. Reagents

Analytical grade sodium acetate (CH₃COONa), potassium per-sulfate (K₂S₂O₈), potassium chloride (KCl), aluminum trichloride (AlCl₃), ferrous sulfate (FeSO₄) ferric chloride hexahydrate (FeCl₃·6H₂O), sodium carbonate (Na₂CO₃), sodium hydroxide (NaOH), ethanol, and acetic acid were purchased from Sinopharm Chemical Reagent Co., Ltd. (Beijing, China). Folin–Ciocalteu’s phenol reagents were obtained from Yuanye Co., Ltd. (Shanghai, China); gallic acid, HEPES buffer (pH 7.5), cysteine, and 5,5'-dithio-bis-(2-nitrobenzoic acid) were obtained from Macklin Co., Ltd. (Shanghai, China). ABTS (purity ≥99.0%), DPPH (purity ≥99.0%), 6-hydroxy-2,5,7,8-tetramethyl-chroman-2-carboxylic acid (Trolox, purity ≥99.0%), and 2,4,6-tripryidyl-1,3,5-triazine (TPTZ, purity ≥99.0%) were obtained from Sigma-Aldrich Co., Ltd (Shanghai, China).

2.2. Plant materials

White and purple garlic (Allium sativum L.) were purchased from a local market in Xuzhou, China. These samples were collected from Jinxiang, Shandong Province, China. Garlic cloves are obtained by removing the coat of the garlic bulb. Then, uniform samples were peeled and cut manually into slices with 3 mm thickness using a knife and stored at 4°C for 7 days before the drying process.

2.3. Drying processing methods

The white and purple garlic slices were dried using FD, HD, VD, and IRD methods. The drying operation was as follows: 1) FD: Garlic slices (500 g) were frozen at −80°C for 12 h and then continuously dried in a freeze dryer for 12 h (Christ Beta 2–8 LD plus, Germany). 2) HD: Garlic slices (500 g) were placed on the heating plate and dried by using a hot-air dryer (JingHong, DHG-9070A, Shanghai, China). The HD air velocity was set to 1.5 m/s, and the air temperature was kept at 60°C 3) VD: Garlic slices (500 g) were placed as a thin layer on a plate and dried by using a vacuum dryer (JingHong DZF-6030, Shanghai, China). The vacuum was set to 0.1 Pa, and the air temperature was kept at 60°C during drying. 4) IRD: Garlic slices (500 g) were placed on the tray of the drying chamber of the infrared dryer (HengYi, YH-H-420, Dongguan, China). The infrared power, wavelength, temperature, and air velocity were set to 675 W, 2.8–3.1 μm, 60°C and 2 m/s, respectively. The distance between the infrared generator and garlic slices was 11 cm. These drying parameters were determined in accordance with previous works (Feng et al., 2020). Fresh white and purple garlic slice (3 mm) was as control. Table 1 shows the final moisture contents and drying times. The dried white and purple garlic slices were crushed and stored at −20°C until use.

2.4. Moisture content

The final moisture content of dried garlic was detected by a quick moisture analyzer (UNLONG, QL-720B, Xiamen, China) (Feng et al., 2020). The drying process was considered complete when the moisture content in the dried garlic slices after drying was less than 10%.

Table 1. The influence of different methods and parameters on drying time, moisture content and volume shrinkage ratio of dried white and purple garlic.

| Samples | Drying methods | Drying time (h) | Moisture content (%) | Volume shrinkage ratio (%) |
|---------|----------------|-----------------|----------------------|---------------------------|
| White   | Fresh          | /               | 10.63 ± 0.23         | 14.83 ± 0.41 Ad            |
|         | FD             | 12.00 ± 0.55    | 8.57 ± 0.13          | 22.20 ± 0.26 Ac            |
|         | HD             | 12.00 ± 0.55    | 9.02 ± 0.25          | 22.20 ± 0.26 Ac            |
|         | IRD            | 10.00 ± 0.94    | 9.44 ± 0.71          | 33.01 ± 0.434 A            |
| Purple  | Fresh          | /               | 58.31 ± 0.05         | 30.99 ± 0.29 Ab            |
|         | FD             | 12.00           | 6.74 ± 0.35          | 11.11 ± 0.158d             |
|         | HD             | 10.50 ± 0.31    | 7.54 ± 0.26          | 23.24 ± 0.333 Ac           |
|         | IRD            | 8.50 ± 0.21     | 8.51 ± 0.27          | 32.21 ± 0.254 A            |
|         | IRD            | 8.00 ± 0.32     | 9.11 ± 0.11          | 26.60 ± 0.433 B            |

Freeze drying: FD; hot air drying: HD; vacuum drying: VD; infrared hot air drying: IRD.

The values are means ± SD of three replicates (n=3). Different letters (a-d) mean the difference significantly at p < .05 in the same garlic variety under different drying methods. Different letters (A and B) mean the difference significantly at p < .05 under the same drying methods in different garlic varieties.

Liofilización: FD; secado por aire caliente: HD; secado al vacío: VD; secado con aire caliente por infrarrojos: IRD.

Los valores son medias ± DE de tres réplicas (n=3). Las letras diferentes (a-d) indican una diferencia significativa (p < .05) en la misma variedad de ajo bajo diferentes métodos de secado. Las letras diferentes (A y B) indican una diferencia significativamente (p < .05) bajo los mismos métodos de secado en diferentes variedades de ajo.
2.5. Volume shrinkage ratio

The volumes of white and purple garlic slices before and after drying were measured by the quartz flour displacement method (Song et al., 2015). The volume shrinkage ratio (VSR) was calculated using the following formula:

\[ VSR = \frac{V1 - V2}{V1} \times 100\% \]

where \( V1 \) and \( V2 \) are the volumes of garlic slices before and after drying (cm\(^3\)), respectively.

2.6. Color parameters

The changes in dried white and purple garlic were measured by a colorimeter (MSEZ-4500 L, Hunter Lab, Virginia, USA). Color was expressed as \( L^* \) (+lightness/−darkness), \( a^* \) (+redness/−greenness), and \( b^* \) (+yellowness/−blueness). Before measurement, the colorimeter was calibrated on a standard white and black plate. The nose cone of the colorimeter was placed on a culture dish containing dried white and purple garlic slices powders (20 g). The \( L^* \), \( a^* \), and \( b^* \) values of dried garlic was obtained from the colorimeter when the culture dish above the light source. The mean values of five readings at different locations on the sample were recorded. Additionally, the whiteness was calculated to describe the change in color on the basis of the \( L^* \), \( a^* \), and \( b^* \) values between fresh and dried white and purple garlic. The whiteness was calculated using the following formula:

\[ \text{Whiteness} = 100 - \sqrt{(100 - L^*)^2 + a^*^2 + b^*^2} \]

2.7. Allicin content

The allicin contents of fresh and dried white and purples garlic samples were determined in accordance with previous methods with minor changes (Han et al., 1995). The fresh white and purple garlic were ground with 50 mM HEPES buffer (pH 7.5). The garlic samples (2 g fresh and 0.5 g dried) with 10 mL 50 mM HEPES buffer (pH 7.5) were incubated for 15 min at 25 ± 1°C. Afterward, the solution was centrifuged at 9408 × g for 5 min, and the supernatant was collected for the determination of allicin contents in fresh and dried white and purple garlic. 5 mL cysteine solution (10 mM) was mixed with 1 mL sample extract or HEPES buffer (as control) and incubated at 25 ± 1°C for 15 min. The reaction solution was diluted 100 times using the buffer solution, and 4.5 mL diluted solution was mixed with 0.5 mL 5S'-dithio-bis-(2-nitrobenzoic acid) (1.5 mM) and allowed to stand at 25 ± 1°C for 15 min. Afterward, the absorbance of the sample (A) or control (A0) at 412 nm was recorded by a spectrophotometer. A blank was also prepared by using HEPES buffer instead of the diluted solution. The allicin content in fresh and dried garlic was calculated using the following formula:

\[ \text{Allicin contents (mg/g DW)} = \frac{(A0 - A) \times d \times v \times 0.004}{m} \]

where \( d \), \( v \), and \( m \) are the dilution factor, extraction volume, and dried weight of the fresh and dried white and purple garlic, respectively.

2.8. Total phenolics contents

The total phenolics contents of fresh and dried white and purple garlic were measured by the Folin–Ciocalteu reagent method in accordance with previous works with slight modifications (Zhou et al., 2017). Briefly, 1 g fresh or 0.5 g dried white and purple garlic was poured into a test tube, and 10 mL 80% aqueous methanol with 1% HCl was added. Then, the mixture was stirred slightly and ultrasonicated for 15 min at 25°C. After the sonication, the samples were centrifuged for 10 min at 9408g (Sigma, model 2-16K, Germany). Next, 1 mL supernatant solution was mixed with 1 mL Folin–Ciocalteu reagent (0.25 mol/L). After 3 min, the reaction mixture was added to 2 mL Na₂CO₃ (15%, w/v) and left to stand for 30 min. The samples were centrifuged for 10 min at 9408g. The absorbance of the supernatant was read at 760 nm with a spectrophotometer. The calibration curves were constructed by absorbance versus the gallic acid concentration (\( y = 95.09 x + 0.0585 \), \( R^2 = 0.99 \)). The total phenolics contents in fresh and dried white and purple garlic were expressed as gallic acid equivalents (GAE, mg/g-DW).

2.9. Antioxidant activity

The antioxidant activities of fresh and dried white and purple garlic were determined by three assays: free radical-scavenging activity by DPPH method, total antioxidant activity by ABTS method, and ferric reducing capability by FRAP method. Trolox with different concentrations was used to obtain the standard curve of three assays. Fresh garlic (2 g) or dried white and purple garlic powders (1 g) were mixed with 20 mL 80% methanol. The mixture was then treated to sonication (40 kHz, 50 W/L) at 25°C for 30 min and then centrifuged (Sigma, model 2-16K, Germany) at 9408g for 10 min. The supernatants were collected and stored at 4°C before conducting the antioxidant activity analysis.

2.9.1. DPPH assay

The DPPH experiments were performed in accordance with the study of Brand-Williams et al. (1995). A total of 2.0 mL supernatant was mixed with 4.0 mL DPPH solution (100 mmol/L) and reacted for 30 min in the dark at room temperature. The absorbance was recorded at 517 nm. The DPPH radical-scavenging capability of fresh and dried garlic was expressed as Trolox equivalent (mmol TE/g-DW).

2.9.2. ABTS assay

The ABTS assay was performed in accordance with the method of Re et al. (1999). Specifically, 50 mL potassium persulfate solution (2.45 mmol/L) and 50 mL ABTS (7 mmol/L) were reacted for 16 h at room temperature in the dark. The free radical ABTS solution was diluted with 80% ethanol to obtain an absorption of 0.70 ± 0.01 at 734 nm before determination. Freshly diluted ABTS solution (3.6 mL) was added to 0.4 mL supernatants. After 6 min incubation, the absorbance was measured at 734 nm. The results were expressed as Trolox equivalent (mmol TE/g-DW).

2.9.3. FRAP assay

FRAP assay was performed in accordance with a previous study (Benzie & Strain, 1996). The TPTZ solution (10 mmol/L) was prepared in HCl (40 mmol/L), FeCl₃·6 H₂O solution (20 mmol/L), and acetate buffer (300 mmol/L) mixed at a ratio of
1:1:10 (mL). The pH of the mixed solution was adjusted to 3.6 with acetic acid to obtain a fresh FRAP reagent. The supernatant (0.2 mL) was mixed with 5 mL FRAP reagent and incubated at 37°C for 30 min. The absorbance was determined at 593 nm, and the results were expressed as Trolox equivalent (mmol TE/g DW).

2.10. Statistical analysis

All results were expressed as the mean and standard deviation (SD) values of at least three replicates. One-way analysis of variance was conducted, and the significance level was set to \( p < .05 \). PCA was conducted to investigate the relationship and differences among the different drying methods. Statistical analyses were performed by using SPSS version 20.0 (SPSS, Inc., Chicago, IL).

3. Results and discussion

3.1. Drying condition and volume shrinkage of white and purple garlic

Figure 1 shows the images of fresh and dried white and purple garlic slices. After the drying treatment, the drying time, moisture contents, and VSR in two kinds of dried garlic slices were obtained (Table 1). White garlic needed more time to dry and to reach a moisture content below 10% compared with purple garlic, except under FD treatments. During the drying process, a material will shrink due to the loss of water. The shrinkage rate of FD treatment was the lowest, whereas the VD treatment caused the highest shrinkage in both kinds of garlic slices. Indeed, the small ice crystals in garlic slices slowly sublime under vacuum drying conditions during the FD treatment. This method is conducive to preserving the original form of garlic (Feng et al., 2019). Previous works also indicated the FD treatment with minimum VSR compared with thermal drying techniques, including HD, VD, and IRD, for the treatment of garlic (Feng et al., 2020). By comparison, heating under vacuum conditions is likely to cause material shrinkage. The drying mechanism and time may influence the VSR degree of garlic (Xu et al., 2020). Thus, the VSR of white garlic was significantly lower than that of purple ones after FD and IRD treatments \( (p < .05) \). Both of drying methods and garlic varieties had significantly affect the VSR of dried garlic.

3.2. Color values in fresh and dried white and purple garlic

Color is generally regarded as the first indicator of the acceptability of food products. The four studied drying methods can lead to significant changes in the \( L^* \) values of white and purple garlic compared with fresh garlic (Table 2). The highest \( L^* \) value was found in the FD treated white and purple garlic slice with its values at 93.57 and 89.67. The dried white and purple garlic after IRD treatment had the lowest \( L^* \) value (76.29 and 69.23) \( \text{(*)} p < .05 \). The \( L^* \) value of purple garlic was higher than that of white garlic in the same drying conditions. The decrease in \( L^* \) means that the dried garlic slices had a dark color compared with the fresh ones, except in FD treatment. The drying process can increase the \( a^* \) value of garlic, and the highest \( a^* \) value was obtained in the IRD groups of white and purple garlic. No significant difference in \( a^* \) values was observed between FD treatment and fresh garlic. The \( a^* \) values of dried purple garlic in HD, VD, and IRD treatments was significantly higher than those of the dried white garlic. FD treatment can significantly decrease the \( b^* \) values, whereas the other three drying treatments can increase the \( b^* \) values compared with the fresh white and purple garlic. Enzymatic and non-enzymatic browning reaction such as Millard reaction may lead to changes in the heating of dried materials during the drying process (Feng et al., 2018). On the other hand, the changes in color values were also attributed to effects, such as shrinkage and changes in reflective characteristics during dehydration (Turkiewicz et al., 2019). The value of whiteness in two varieties of dried garlic after FD treatment was significantly higher than that of the fresh ones. HD, VD, and IRD treatment significantly decreased the whiteness of dried white and purple garlic. Feng et al. also observed the significant decrease in the whiteness of garlic in these drying treatments compared with FD (Feng et al., 2019). Cui et al., (2003) reported that the color changes of food materials may related to the drying time and

![Figure 1](image-url)
temperature change during the drying process. Local overheating during the drying process can also cause the color to darken (Baysal et al., 2003). In addition, the whiteness of dried white garlic was significantly higher than that of the purple one in the four drying treatments in this work. The small size, short drying time and low moisture contents were found in purple garlic slices (Table 1 and Figure 1). Hence, drying characteristics, garlic structure, and drying time may cause the different changes in whiteness between white and purple garlic.

3.3. Allicin contents of fresh and dried white and purple garlic

Allicin as an organic sulfur compound is an important flavoring and active substance in garlic (Lilia et al., 2017; Rahman, 2007). Figure 2 shows the effect of different drying methods on the allicin contents of white and purple garlic. The allicin contents of fresh white and purple garlic were 1.78 and 2.70 mg/g, respectively. The high contents of allicin in purple garlic may be related to the cultivars and source (Liu et al., 2020). As shown in Figure 2, the contents of allicin in FD, HD, VD and IRD treated white garlic were 1.75, 1.24, 1.15, and 1.30 mg/g, respectively. The allicin contents of four dried purple garlic were significantly higher than those of dried white garlic in the same drying treatment, with values of 2.60, 1.32, 1.74, and 2.67 mg/g (p < .05). FD treatment can preserve the allicin contents of both kinds of garlic. Aware and Thorat also observed that the FD treatment can preserve the allicin in garlic compared with thermal treatment (Aware & Thorat, 2011). HD, VD, and IRD treatments can significantly decrease the allicin contents of white garlic compared with FD treatment. These results agree with those of previous works (Rahman, 2007; Ratti et al., 2007). The loss of allicin may be due to degradation under heating treatment. Méndez-Lagunas and Castaigne (2008) reported that alliinase can be denatured at 42°C and inactivated above 60°C as the synthesis of allicin decreases. From the literature, the increased degradation of allicin in dried garlic was recorded with the increase in drying time (Aguilera, 2003; Aware & Thorat, 2011). In this work, the allicin preservation rates in white garlic dried by HD, VD, and IRD were 65.91%, 70.82%, and 74.49%, respectively. HD and VD treatment preserved 49.73% and 65.80% of the allicin contents of dried purple garlic compared with the FD treatment, respectively. No significant difference was observed in the allicin contents of dried purple garlic under FD and IRD treatments. The microstructure and water activity of garlic also have a significant effect on the allicin content of garlic, except the drying time and methods of drying (Ratti et al., 2007). These differences between white and purple garlic may lead to varied changes in their allicin contents. The differences in heat resistance of different varieties of garlic alliinase may also lead to variations in the content of this compound (Martins et al., 2016). Thus, in addition to drying conditions (method, time, and temperature), the variety of garlic should be considered when determining the stability of allicin. The allicin contents in dried purple garlic was significantly higher than that of dried white garlic in this work.

3.4. Total phenolics contents of fresh and dried white and purple garlic

Phenolic compounds are also important active ingredients in garlic (Chen et al., 2013). Figure 3 shows the effects of

Figure 2. The allicin content of dried white and purple garlic slices. Each value represents the mean of three replicates, and error bars indicate standard deviation (± SD). Different letters (a–d) mean the significant difference between the fresh and drying methods. (p < .05). Different letters (A and B) mean the difference significantly at p < .05 under the same drying methods in different garlic variety.

Figure 2. Contenido de alcina en rodajas secadas de ajo blanco y ajo morado. Cada valor representa la media de tres réplicas y las barras de error indican la desviación estándar (± DE). Las letras diferentes (a–d) indican una diferencia significativa entre los métodos fresco y seco (p < .05). Las letras diferentes (A y B) indican una diferencia significativa (p < .05) bajo los mismos métodos de secado en diferentes variedades de ajo.

Table 2. The values of L*, a*, and b* of the dried white and purple garlic slices.

| Samples | Drying methods | L*       | a*       | b*       | Whiteness |
|---------|----------------|----------|----------|----------|-----------|
| White   | Fresh          | 90.74 ± 0.38b | 1.04 ± 0.06d | 21.07 ± 0.13d | 76.96 ± 0.21b |
|         | FD             | 93.57 ± 1.21a | 1.45 ± 0.24cd | 11.11 ± 0.15e | 87.04 ± 0.51a |
|         | HD             | 83.24 ± 0.09d | 3.06 ± 0.11b | 26.60 ± 0.43b | 68.41 ± 0.41d |
|         | VD             | 86.76 ± 1.29c | 2.11 ± 0.75c | 23.24 ± 0.33c | 73.14 ± 0.45c |
|         | IRD            | 76.29 ± 0.38e | 6.45 ± 0.23a | 33.21 ± 0.25a | 58.69 ± 0.45e |
| Purple  | Fresh          | 87.51 ± 0.55b | 0.55 ± 0.03d | 21.80 ± 0.66c | 74.86 ± 0.52b |
|         | FD             | 89.67 ± 0.97a | 0.69 ± 0.18d | 14.83 ± 0.41d | 81.89 ± 0.55a |
|         | HD             | 76.23 ± 0.37d | 5.36 ± 0.24b | 30.99 ± 0.29b | 60.59 ± 0.46d |
|         | VD             | 84.81 ± 1.23c | 2.92 ± 0.42c | 22.20 ± 0.26c | 72.92 ± 0.56c |
|         | IRD            | 69.23 ± 0.27e | 9.56 ± 0.29a | 33.01 ± 0.43a | 53.87 ± 0.53e |

Freeze drying: FD; hot air drying: HD; vacuum drying: VD; infrared hot air drying: IRD.

The values are means ± SD of five replicates (n=5). Different letters mean the difference significantly at p < .05.

Liofilización: FD; secado por aire caliente: HD; secado al vacío: VD; secado al aire caliente por infrarrojos: IRD.

Los valores son medias ± DE de cinco réplicas (n=5). Las letras diferentes indican una diferencia significativa (p < .05).

Phenolic compounds are also important active ingredients in garlic (Chen et al., 2013). Figure 3 shows the effects of...
different drying methods on the total phenolics contents of dried white and purple garlic. The total phenolics contents of fresh white and purple garlic were 3.50 and 6.02 mg/g, respectively. No significant differences were observed in the total phenolics between FD and fresh white and purple garlic. Drying treatments, including HD, VD, and IRD, can significantly decrease the total phenolics contents of white and purple garlic compared with the FD treatment. The FD treatment preserves the total phenolics contents in various foodstuffs (blue black mulberry and kiwi) better than thermal drying (Chen et al., 2013; Izli et al., 2016). The total phenolics contents of white garlic under four drying treatments were 3.48, 2.36, 2.55, and 2.58 mg/g. The dried purple garlic had higher total phenolics contents in the same drying methods compared with white garlic, with values reaching 5.93, 2.61, 3.52, and 4.33 mg/g. Heat treatment will also cause a large amount of total phenol loss in garlic (Zhou et al., 2017). Compared with the FD treatment, HD, VD, and IRD resulted in losses of total phenolics contents of white garlic, with values of 32.27%, 26.70%, and 25.86%, respectively. HD caused the highest loss total phenolics contents (56.03%), whereas the IRD treatment preserved 73.02% of the total phenolics contents of purple garlic. Meanwhile, the length of heating time can explain the difference in the total phenolics in dried jujube fruits affected by cultivar and drying method (Angel et al., 2013). The preservation rate of total phenolics contents in purple garlic was higher than that of white garlic in four drying groups, which may be due to its lower drying time.

3.5. Antioxidant activity of fresh and dried white and purple garlic

In this work, the antioxidant activity of fresh and dried white and purple garlic was evaluated using DPPH, FRAP, and ABTS assay (Table 3). After the drying process, white and purple garlic in the IRD groups had the highest DPPH-scavenging ability (3.57 and 6.64 mmol TE/g-DW, respectively), and the two drying methods included FD and IRD also increased the DPPH values compared with fresh garlic. The highest values of FRAP were also observed in white and purple garlic under IRD treatment, and their values were 3.16 and 5.70 mmol TE/g-DW, respectively. The highest ABTS values were observed in the white garlic dried by FD treatment, and no significant differences were observed in the ABTS values among fresh, FD-, and IRD-treated purple garlic. After the HD treatment, the DPPH, ABTS, and FRAP values in white and purple garlic decreased significantly, and HD treatment achieved the lowest DPPH (2.81 and 4.18 mmol TE/g-DW), followed by ABTS (1.54 and 2.05 mmol TE/g-DW) and FRAP (2.49 and 3.29 mmol TE/g-DW). FD and IRD can promote the ABTS and FRAP values of dried garlic compared with fresh garlic in previous work (Feng et al., 2020). HD and VD treatments can significantly decrease the antioxidant capacities of various foodstuffs (Chuyen et al., 2017; Yuan et al., 2015). In this work, decreases in the DPPH, ABTS, and FRAP values of dried white and purple garlic in HD were also recorded. IRD and FD treatments can preserve the allicin and total phenolics contents of garlic well. Thus, its antioxidant capacity was remarkably preserved after these treatments. The DPPH, ABTS, and FRAP values of fresh purple garlic were higher than those of white garlic (5.43, 2.59, and 4.51 mmol TE/g-DW, respectively). Meanwhile, the values of dried purple garlic were also higher than those of dried white garlic after the same drying process, and this finding was related to the higher allicin and total phenolics contents of dried purple garlic compared with the white ones. Numerous researchers have discovered the high correlations between total phenolics contents, allicin contents, and antioxidant activity of dried garlic (Salehi et al., 2019; Turkiewicz et al., 2019).

3.6. Principal component analysis

The normalized data, including color values, whiteness, allicin, total phenolics, and antioxidant capacities values, were used to investigate the similarities and differences between the white and purple garlic after the drying process through principal component analysis (PCA). Three PCs were extracted with eigenvalues higher than 1 based on Kaiser’s rules, and they explained 92.617% of the total variance. The PCA results indicated that the dried white and purple garlic under different drying methods were successfully distinguished. Figures 4 a–c show the loading plots between PC1 and other PCs obtained by PCA. PC1 accounted for 37.332% of the total variation and was positively correlated with total phenolics contents (0.86), allicin contents (0.94), DPPH (0.98), ABTS (0.94), and FRAP (0.92). These factors were mainly related to the functional components and antioxidant activities in fresh and dried white and purple garlic. PC2 explained 34.842% of the total variation and showed a highly positive correlation with a* (0.90) and b* (0.98) and a negative correlation with L (−0.96) and whiteness (−0.99). PC2 was mainly the color change of garlic before and after drying. For PC3 (20.443%), physical characteristics changes including drying time, moisture contents, and VSR were the main contributors with values of 0.97, −0.97, and −0.54, respectively. The three PCs showed the differences and similarities of dried white and purple garlic.
Table 3. The influence of different drying methods on the antioxidant activity of dried white and purple garlic slices.

| Samples | Drying methods | Antioxidant activity (mmol TE/g. DW) |
|---------|----------------|-------------------------------------|
|         |                | DPPH | ABTS | FRAP   |
| White   | Fresh          | 3.10 ± 0.02Bb | 1.83 ± 0.07Bb | 2.86 ± 0.04Bb |
|         | FD             | 3.52 ± 0.05 Ba | 2.09 ± 0.09 Ba | 2.70 ± 0.06Bc |
|         | HD             | 2.81 ± 0.02Ba | 1.54 ± 0.04Bc | 2.49 ± 0.05Bd |
|         | VD             | 3.09 ± 0.04Bc | 1.74 ± 0.08Bb | 2.50 ± 0.11Bd |
| Purple  | Fresh          | 3.57 ± 0.04Ba | 1.85 ± 0.12Bb | 3.16 ± 0.07Ba |
|         | FD             | 5.43 ± 0.05Ac | 2.59 ± 0.07Aab | 4.51 ± 0.04Ab |
|         | HD             | 5.97 ± 0.10Ab | 2.68 ± 0.09Aab | 4.35 ± 0.14Abc |
|         | VD             | 4.18 ± 0.02Ae | 2.05 ± 0.04Aac | 3.29 ± 0.06Ad |
|         | IRD            | 4.75 ± 0.05Ad | 2.42 ± 0.25Ab  | 4.08 ± 0.29Ac |
|         |                | 6.64 ± 0.02Aa | 2.85 ± 0.12Aa  | 5.70 ± 0.04Aa |

Freeze drying: FD; hot air drying: HD; vacuum drying: VD; infrared hot air drying: IRD.

The values are means ± SD of five replicates (n=5). Different letters (a–d) mean the difference significantly at p < .05 in the same garlic variety under different drying methods. Different letters (A and B) mean the difference significantly at p < .05 under the same drying methods in different garlic variety.

Liofilización: FD; secado por aire caliente: HD; secado al vacío: VD; secado por aire caliente infrarrojo: IRD.

Los valores representan las medias ± DE de cinco réplicas (n=5). Las letras distintas (a–d) indican una diferencia significativa (p < .05) en la misma variedad de ajo bajo diferentes métodos de secado. Las letras distintas (A y B) indican una diferencia significativamente (p < .05) bajo los mismos métodos de secado en diferentes variedades de ajo.

in terms of color, physical properties, and antioxidant properties under different drying methods.

Figures 4 a1–c1 show the score plots among the PCs of white and purple garlic samples under different drying methods. The locations of fresh and dried purple garlic are on the right of Figure 4 a1 based on the higher total phenolics contents, allicin contents, and antioxidant capacities (DPPH, ABTS, and FRAP) compared with those of fresh and dried white garlic. For PC2, the white and purple garlic dried by FD are located at the bottom of Figure 4 a1 based on the color changes (L*, a*, and b* and whiteness). The IRD treatment samples are located in the upper part of Figure 4 a1 due to the significant changes in the color of white and purple garlic before and after drying. The reason for the position of the white and purple garlic samples under different processing methods in Figure 4 b1 was similar to that for the result in Figure 4 a1. The significant changes in drying time, moisture contents, and VSR also contributed to the location of fresh and dried garlic samples in Figure 4 c1. Previously researches results shown that different drying methods had different effects on the quality of garlic such as color, functional ingredients and antioxidant activities (Feng et al., 2020; Rahman, 2007). This study has similar findings and also found the difference between white and purple garlic after different drying treatments based on the PCA results.

Figure 4. Loading plots and score plots obtained a partir del análisis de componentes principales de las variables seleccionadas. A, B y C indican los gráficos de carga de los parámetros analizados (PC1-PC2, PC1-PC3 y PC2-PC3); A1, B1 y C1 presentan los gráficos de puntuación de los métodos en fresco y de secado (PC1-PC2, PC1-PC3 y PC2-PC3).
4. Conclusion

In conclusion, the different drying treatments (FD, HD,VD, and IRD) can significantly affect the colors, bioactive compounds, and antioxidant capacities of white and purple garlic. The white and purple garlic had the lowest VSR in FD treatment. The highest whiteness of dried white and purple garlic was obtained in the FD treatment. FD and IRD treatment can preserve well active substance including allicin and total phenolics of white and purple garlic. Meanwhile, the FD and IRD-treated white and purple garlic had higher antioxidant capacities including DPPH, ABTS, and FRAP Especially, the allicin and total phenolics contents in dried purple garlic was higher than the white one under the same drying methods. The antioxidant capacities of dried purple garlic were also significantly higher than the dried white garlic. The PCA results revealed the evident differences between white and purple garlic before and after the drying treatment. Therefore, the IRD method (infrared power, wavelength, temperature, and air velocity: 675 W, 2.8–3.1 μm, 60°C and 2 m/s) and purple garlic slices may be suitable to obtain high-quality garlic powder products.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
This work was supported by Xuzhou Basic Research Project (Young Talents) (KC21031), Science and Technology Planning Project of Jiangsu Province of China (XZ-SZ201849, XZ-SZ201946, XZ-SZ202130 and XZ-SZ202148).

References
Aguilera, J. M. (2003). Drying and dried products under the microscope. Food Science and Technology International, 9(3), 137–143. https://doi.org/10.1177/108201320034640
Angel, C.-S., Figiel, A., Hernández, F., Melgarejo, P., Lech, K., & Carbonell-Barrachina, A. A. (2013). Chemical composition, antioxidant capacity, and sensory quality of pomegranate (Punica granatum L.) arils and rind as affected by drying method. Food and Bioprocess Technology, 6(7), 1644–1654. https://doi.org/10.1007/s11947-010-923
Angeles, T. M. M., Jesús, P. A., Rafael, M. R., & Tania, M. A. (2016). Evolution of some physicochemical and antioxidant properties of black garlic whole bulbs and peeled cloves. Food Chemistry, 199, 135–139. https://doi.org/10.1016/j.foodchem.2015.11.128
Aware, R. S., & Thorat, B. N. (2011). Garlic under various drying study and its impact on allicin retention. Drying Technology, 29(13), 1510–1518. https://doi.org/10.1080/07373937.2011.578230
Bayyal, T., Icier, F., Ersus, S., & Yildiz, H. (2003). Effects of microwave and infrared drying on the quality of carrot and garlic. European Food Research and Technology, 218(1), 68–73. https://doi.org/10.1007/s00217-003-0791-3
Benzie, I. F. F., & Strain, J. J. (1996). The Ferric Reducing Ability of Plasma (FRAP) as a measure of “Antioxidant Power”. The FRAP Assay. Analytical Biochemistry, 239(1), 70–76. https://doi.org/10.1016/0003-2697(96)00229-2
Brand-Williams, W. M., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidative activity. LWT - Food Science and Technology, 28(1), 25–30. https://doi.org/10.1016/0023-6438(95)80008-5
Chen, S., Shen, X., Cheng, S., Li, P., Du, J., Chang, Y., & Meng, H. (2013). Evaluation of garlic cultivars for polyphenolic content and antioxidant properties. PLoS One, 8(11), e79730. https://doi.org/10.1371/journal.pone.0079730
Chen, Q. Q., Li, Z., Bi, J., Zhou, L., Yi, J., & Wu, X. (2017). Effect of hybrid drying methods on physicochemical, nutritional and antioxidant properties of dried black mulberry. LWT - Food Science and Technology, 80, 178–184. https://doi.org/10.1016/j.lwt.2017.02.017
Chuyen, H. V., Roach, P. D., Golding, J. B., Parks, S. E., & Nguyen, M. H. (2017). Effects of four different drying methods on the carotenoid composition and antioxidant capacity of dried Gac peel. Journal of the Science of Food and Agriculture, 97(5), 1656–1662. https://doi.org/10.1002/ps.9718
Cui, Z. W., Xu, S. Y., & Sun, W. D. (2003). Dehydration of garlic slices by combined microwave-vacuum and air drying. Drying Technology, 21(7), 1173–1184. https://doi.org/10.1080/07373937.201203174
Fei, M. L., Tong, L., Wei, L., & Yang, L. D. (2015). Changes in antioxidant capacity, levels of soluble sugar, total polyphenol, organosulfur compound and constituents in garlic clove during storage. Industrial Crops and Products, 69, 137–142. https://doi.org/10.1016/j.indcrop.2015.02.021
Feng, Y. B., Wu, B. G., Yu, X. J., ElGasmis, A., Yagoub, A., Sarpong, F., & Zhou, C. S. (2018). Effect of catalytic infrared dry-blanching on the processing and quality characteristics of garlic slices. Food Chemistry, 266, 309–316. https://doi.org/10.1016/j.foodchem.2018.06.012
Feng, Y. B., Zhou, C. S., Yagoub, A. E. A., Sun, Y. H., Owusu-Ansah, P., Yu, X. J., Wang, X. L., Wu, X., Zhang, J., & Ren, Z. F. (2019). Improvement of the catalytic infrared drying process and quality characteristics of the dried garlic slices by ultrasound-assisted alcohol pretreatment. LWT - Food Science and Technology, 116, 10857. https://doi.org/10.1016/j.lwt.2019.108577
Feng, Y. B., Tan, C. P., Zhou, C. S., Yagoub, A. E. A., Xu, B. G., Sun, Y. H., Ma, H. L., Xu, X., & Yu, X. J. (2020). Effect of freeze-thaw cycles pretreatment on the vacuum freeze-drying process and physico-chemical properties of the dried garlic slices. Food Chemistry, 324, 126883. https://doi.org/10.1016/j.foodchem.2020.126888
Feng, Y. B., Wu, B. G., Yu, X. J., Yagoub, A. E. A., Ma, H. L., Sun, Y. H., Xu, X., Yu, X. J., & Zhou, C. S. (2020). Role of drying techniques on physical, rehydration, flavor, bioactive compounds and antioxidant characteristics of garlic. Food Chemistry, 343, 128404. https://doi.org/10.1016/j.foodchem.2020.128404
Han, J. L., Han, G., & Han, P. (1995). A spectrophotometric method for quantitative determination of allin and total garlic thiosulfonates. Analytical Biochemistry, 225(1), 157–160. https://doi.org/10.1006/abio.1995.1124
He, Y., Fan, G. J., Wu, C. E., Kou, X. H., Li, T. T., Tian, F., & Gong, H. (2019). Influence of packaging materials on postharvest physiology and texture of garlic cloves during refrigeration storage. Food Chemistry, 298, 125019. https://doi.org/10.1016/j.foodchem.2019.125019
Hui, S. (2020). Anti-Inflammatory and intestinal microbiota modulation properties of jinxiang garlic (Allium sativum L.) polysaccharides toward dextran sodium sulfate-induced colitis. Journal of Agricultural and Food Chemistry, 68(44), 12295–12309. https://doi.org/10.1021/acs.jafc.0c04773
Izli, N., Izli, G., & Taskın, O. (2016). Drying kinetics, colour, total phenolic content and antioxidant capacity properties of kiwi dried by different methods. Journal of Food Measurement and Characterization, 11(1), 1–11. https://doi.org/10.11694/1-9372-6
Kim, J. H., Nam, S. H., Rico, C. W., & Mi, Y. K. (2012). A comparative study on the antioxidative and anti-allergic activities of fresh and aged black garlic extracts. International Journal of Food Science and Technology, 47(6), 1176–1182. https://doi.org/10.1111/j.1365-2621.2012.02957.x
Lilia, M. L., Juan, R. R., David, R. V., & Anabel, L. O. (2017). Changes in physical properties and relations with allin degradation during convective drying of garlic. Journal of Food Measurement and Characterization, 11(3), 1227–1232. https://doi.org/10.11694/01-9499-0
Liu, P., Weng, R., Xu, Y., Feng, Y., He, L., Qian, Y., & Qiu, J. (2020). Morphologic changes in different tissues of garlic plant during growth. Journal of Agricultural and Food Chemistry, 68(44), 12467–12475. https://doi.org/10.1021/acs.jafc.0c04178
Liu, P. X., Weng, R., Sheng, X. J., Wang, X. L., Zhang, W. H., Qian, Y. Z., & Qiu, J. (2020). Profiling of organosulfur compounds and amino acids in garlic from different regions of China. Food Chemistry, 305, 125499. https://doi.org/10.1016/j.foodchem.2019.125499
Martins, N., Petropoulos, S., & Ferreira, I. C. (2016). Chemical composition and bioactive compounds of garlic (Allium sativum L.) as affected by
pre- and post-harvest conditions: A review. Food Chemistry, 211, 41–50. https://doi.org/10.1016/j.foodchem.2016.05.029
Méndez-Lagunas, L. L., & Castaigne, F. (2008). Effect of temperature cycling on allinase activity in garlic. Food Chemistry, 111(1), 56–60. https://doi.org/10.1016/j.foodchem.2008.03.035
Montaño, A., Beato, V. M., Mansilla, F., & Orgaz, F. (2011). Effect of genetic characteristics and environmental factors on organosulfur compounds in garlic (Allium sativum L.) grown in Andalusia, Spain. Journal of Agricultural and Food Chemistry, 59(4), 1301–1307. https://doi.org/10.1021/jf104494j
Rahman, M. S. (2007). Allicin and other functional active components in garlic: Health benefits and bioavailability. International Journal of Food Properties, 10(2), 245–268. https://doi.org/10.1080/10942910601113327
Rahman, M., Al-Shamsi, Q., Bengtsson, G., Sablani, S., & Al-Alawi, A. (2009). Drying kinetics and allicin potential in garlic slices during different methods of drying. Drying Technology, 27(3), 467–477. https://doi.org/10.1080/07373930802683781
Ratti, C., Araya-Farias, M., Méndez Lagunas, L., & Mahlouf, J. (2007). Drying of garlic (Allium sativum) and its effect on allicin retention. Drying Technology, 25(2), 349–356. https://doi.org/10.1080/0737393060120100
Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Biology & Medicine, 26(9-10), 1231–1237. https://doi.org/10.1016/S0891-5849(98)00315-3
Salehi, B., Zucca, P., Ohran, I. E., Azzini, E., Adestunji, C. O., Mohammed, S. A., & Ahmad, Z. (2019). Allicin and health: A comprehensive review. Trends Food Science and Technology, 86, 502–516. https://doi.org/10.1016/j.tifs.2019.03.003
Shi, X. F., Chu, J. Z., Zhang, Y. F., Liu, C. Q., & Yao, X. Q. (2017). Nutritional and active ingredients of medicinal chrysanthemum flower heads affected by different drying methods. Industrial Crops and Products, 104, 45–51. https://doi.org/10.1016/j.indcrop.2017.04.021
Somman, A., & Siwarungson, N. (2015). Comparison of antioxidant activity and tyrosinase inhibition in fresh and processed white radish, garlic and ginger. Journal of Food Measurement and Characterization, 9, 369–374. https://doi.org/10.1007/s11694-015-9244-5
Song, C. F., Cui, Z., Jin, G. Y., Mujumdar, A. S., & Yu, J. F. (2015). Effects of four different drying methods on the quality characteristics of peeled litchis (Litchi chinensis Sonn.). Drying Technology, 33(5), 583–590. https://doi.org/10.1080/07373937.2014.963203
Turkiewicz, I. P., Wojdyla, A., Lech, K., Tkacz, K., & Nowicka, P. (2019). Influence of different drying methods on the quality of Japanese quince fruit. LWT- Food Science and Technology, 114, 108416. https://doi.org/10.1016/j.lwt.2019.108416
Wojdyla, A., Figiel, A., & Oszmiana, J. (2009). Effect of drying methods with the application of vacuum microwaves on the bioactive compounds, color, and antioxidant activity of strawberry fruits. Journal of Agricultural and Food Chemistry, 57(4), 1337–1343. https://doi.org/10.1021/jf802507j
Xu, Y. Y., Xiao, Y. D., Laginka, C., Li, D. J., Liu, C. Q., Jiang, N., Song, J. F., & Zhang, M. (2020). A comparative evaluation of nutritional properties, antioxidant capacity and physical characteristics of cabbage (Brassica oleracea var. Capitata var L) subjected to different drying methods. Food Chemistry, 309, 124935. https://doi.org/10.1016/j.foodchem.2019.06.002
Yan, J. K., Wang, C., Yu, Y. B., Wu, L. X., Chen, T. T., & Wang, Z. W. (2020). Physicochemical characteristics and in vitro biological activities of polysaccharides derived from raw garlic (Allium sativum L) bulbs via three-phase partitioning combined with gradient ethanol precipitation method. Food Chemistry, 339, 128081. https://doi.org/10.1016/j.foodchem.2020.128081
Younis, M., Abdelkarim, D., & El Abdein, A. Z. (2018). Kinetics and mathematical modelling of infrared thin-layer drying of garlic slices. Saudi Journal of Biological Sciences, 25(2), 332–338. https://doi.org/10.1016/j.sjbs.2017.06.011
Yuan, J., Hao, L. J., Wu, G., Wang, S., Duan, J. A., Xie, G. Y., & Qin, M. J. (2015). Effects of drying methods on the phytochemicals contents and antioxidant properties of chrysanthemum flower heads harvested at two developmental stages. Journal of Function Foods, 19, 786–795. https://doi.org/10.1016/j.jff.2015.10.008
Zhou, L. Y., Guo, X. N., Bi, J. F., Yi, J. Y., Chen, Q. Q., Wu, X. Y., & Zhou, M. (2017). Drying of garlic slices (Allium sativum L.) and its effect on thiosulfonates, total phenolic compounds and antioxidant activity during infrared drying. Journal of Food Processing and Preservation, 41(1), e12734. https://doi.org/10.1111/jfpp.12734