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Research paper

Process optimization based on carrot powder color characteristics

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ABSTRACT

The carotenoid content indicates the processing quality of carrot powder. The carotenoid content of carrot powder was analyzed using digital image processing technology and color analysis technology, and an estimation model between the carotenoid content and color characteristics was established. The carrot was dried using different drying methods. The verification test result shows that model fitting is prominent and the test error is small and promptly improves the reference of testing for the carotenoid content of carrot powder. The processing parameters of the carrot powder with the highest carotenoid content are as follows: the carrot was frozen and thawed using the freeze drying method; the powder particle size is 80–120 mesh.

1. Introduction

Carrots have high nutrition, health care and medical values. When a carrot is turned into a powder with microstructure, its surface area and porosity significantly increase and the product dispersivity, solubility and functionality noticeably strengthen, which makes it easily digested and absorbed in human bodies (Zheng and Xia, 2006; Ma et al., 2008; Gong et al., 2006). Carrots are rich in cellulose, sugar, protein and other biologic activity materials, which lead to greater stickiness, higher toughness and worse heat-resistance during the pulverizing process, so pulverizing and classification become much more difficult (Gai, 1999). In particular, when the material granularity gradually decreases during the pulverizing process, its surface area sharply increases; particles with high superficial energy are easily agglomerated; when the particles are much smaller, the agglomeration trend is more prominent; and when the particles are pulverized to some granularity, the dynamic equilibrium between pulverization and agglomeration appears. Furthermore, the pulverizing process deteriorates because of the increased particle agglomeration (Gong and Zeng, 2009). Therefore, ultrafine grinding technology has practical significance regarding carrot powder.

Carotenoid contains a hydrocarbon with an unsaturated double bond or its oxygen derivatives, which are unstable and sensitive to oxygen, light, heat and acid. The decomposition speed of carotenoid increases with increasing temperature. Carotenoid easily breaks down when it is exposed to light, and carrot micro-powder has much higher chances of contacting light to oxidize and break down when the particle size decreases and the surface area increases. It is necessary to study the effects on the carotenoid content in carrot powder under different process conditions to improve the quality of carrot ultra-micro powder. However, the routine testing process of extracting carotenoid in carrot powder using an extracting agent and subsequently measuring the carotenoid content by testing the absorbency is notably complicated and increases the testing error (Fan et al., 2001). Therefore, a rapid test of the carotenoid content in carrot powder has practical significance.

Suzuki. T's study (Suzuki, 1995) confirmed that there is a significant correlation between the color characteristics G/(R + G + B) and the chlorophyll content in broccoli seedling leaves. Adamsen F.J has proven that the chlorophyll content in wheat leaves is well correlated to G/R (Adamsen et al., 1999). Li Y used a digital camera to obtain color images of tomatoes and to extract its color feature values using the image processing software. The experiment indicates that color features are highly correlated to the nitrogen index (Li et al., 2007). Cai HC has verified that G/R and R/(R + G + B) are the main color characteristic parameters of the carotenoid content (Cai et al., 2006). The carotenoid content of carrot powder was analyzed using digital image processing technology and color analysis technology, and an estimation model between the carotenoid content and the color characteristics was established. Based on these results, in an experimental study with different pre-

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processing methods (fresh carrot, cured carrot and froze thawing carrot were included), carrot was dried using different techniques: vacuum freeze drying, vacuum drying, microwave drying and hot-air drying; then, carrot powder with different particle sizes were processed. In the orthogonal test analysis, the processing parameters of the carrot powder with the highest carotenoid content were determined. The study conclusion on carrot powder production processing has guiding significance.

2. Materials and methods

2.1. Material

The carrot used in the experiments is red core No. 4, and the average moisture content of the raw carrot is 91%.

2.2. Methods

2.2.1. Equipments

FD-5 vacuum freezing dryer (Beijing Boyikang Technology Company); WD850B microwave oven (Guangdong Shunde Gelanshi Group); DZF-6090 vacuum dryer (Shanghai Jinghong Laboratory Equipment Company); JY2002 electronic balance (Shanghai Exact Science Instrument Company, 0.001 g); 101-0A electrothermal constant-temperature dry box (Shanghai Sunshine Experiment Instrument Company); DWF-1088 multi-function food processor (Yangzhou Wenfeng electric appliance company); centrifuge (Japan Rili Company); electric heating constant-temperature water-bath pot (Changzhou Guohua Electric Appliance company).

2.2.2. Preparation of carrot powder

The raw carrot were sliced with the size of 7.1 × 5.5 mm (w × t) and then did the pre-treatments of cooking and freezing-thawing. Subsequently, the carrot were dried using vacuum drying, freeze drying, heated-air drying and the microwave drying method, respectively. Finally the carrot powder can be obtained through grinding and screening.

Heated-air drying, microwave drying, vacuum drying and freeze drying were compared in this study (Che and Zhu, 2006; Tao, 2004). The carrot's average moisture content after drying is 5%. The freeze drying conditions were: pressure of the drying chamber of 150 Pa; temperature of the heater plate of 40 °C. The vacuum drying conditions were: pressure of the drying chamber of 0.07 MPa; temperature of the heater plate of 65 °C. The microwave drying condition was: 20 min with moderate heat (the power is 540 W) at first and low heat (the power is 180 W) subsequently. For heated-air drying, the temperature was 65 °C. After drying, the carrot was mashed with the multi-function pulverizer and screened through 80–120 meshes, 160–200 meshes and more than 240 meshes; then, the carrot powder sample was obtained.

2.2.2.1. Pretreatments of the carrot were as follows. Freezing-thawing treatment: a type of cell disruption technology with low-temperature freezing and high-temperature melting was applied to the carrot. By freezing-thawing, the carrot slices and the carotenoid extraction could be improved (Chen et al., 2004). The freezing-thawing treatment in the experiment was as follows. First, raw carrot slices were placed in the cold trap (−62 °C) of the freeze drier for 5 h. Then, they were brought from the cold trap to the natural environment and maintained for 1 h. Then, they were placed in the cold trap again for 5 h. Finally, they were thawed in room-temperature condition. The melted carrot slices are experimental materials for the freezing-thawing treatment.

Cooked treatment: To release the nutrition ingredient, the carrot cell wall was destroyed using microwaves at high temperature (Chinese National Standards, 1990a,b). For the cooked treatment in this study, a 750 W microwave was used to process raw carrot slices for 3 min. After the processing, the carrot was cooked.

2.2.3. Equipment of image extraction and selection of the color characteristic parameter

Equipment of image extraction: The digital camera model used was CANON-DIGITALIXUS960. The image processing software used was Adobe Photoshopcs8.0.

Determination of the color characteristic parameter: There are commonly RGB and HSI color coordinate systems for digital image processing. The RGB color coordinate system is based on the three colors: red (R), green (G) and blue (B); other colors are blending weighted using the three basic colors.

In the RGB color coordinate system, if we only consider the chroma instead of the light intensity, we only know the relative value of R, G and B. The relative values of r, g and b are called chromaticity coordinates, the calculation formulas of which are as follows:

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B} \quad (1)$$

Extract method of color characteristic parameter: The digital model was used, where digital images of the carrot powder of various processes were taken in indoor light. Approximately 50 g carrot powder was used for taking a photograph of digital images.

The exposure time and color images were controlled using the digital camera automatic exposure programmer. An image resolution of 2048 by 1536 pixels was used. RGB color images were obtained and placed in a computer in bmp format, each of which had a size of 9.0 MB. Adobe Photoshopcs8.0 was used for image analysis and color feature extraction. The image of carrot powder was selected by the “magic wand” tool in the “tools” panel. Then, the histogram programmer in the drop-down menu of “window” was selected to read the image mean of red (R), green (G) and blue (B) in each channel. Because the background besides the powder digital image was artificially removed in the aforementioned process of image treatment, which reduces the effect of “image noise” in the image-processing results, different color characteristics of the digital image can be taken instead of the actual color information of carrot powder (Li et al., 2007).

2.2.4. Measurement of carotenoid content in carrot powder

Base on Chinese standard GB12291-90, the carotenoid of carrot powder was extracted using an extraction solvent (chloroform:methanol (v:v) = 2:1). The absorbance was measured at λ max of 458 nm, when the extraction solvent was treated as a blank space (Chinese National Standards, 1990a,b; Cao et al., 2003; Gong, 2008).

According to the test results, we calculated the carotenoid content as follows.

$$M = \frac{A \times 400}{\mathrm{m}} \quad (2)$$

where M is the carotenoid content (mg/kg); A is the maximum absorbance of the measurement; m is the measurement of the sample; and 400 is the conversion factor.

2.2.5. Statistical analysis

The single variable linear regression and the multivariate linear regression analysis methods were used to analyze the correlation between the carotenoid content and the color characteristics in carrot powder. Differences among the mean values of the experimental data were determined using Duncan's multiple range test