

Effect of dynamic high pressure microfluidization on physical properties of goji juice, mango juice and carrot puree

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Abstract. In this study, the effects of dynamic high pressure homogenization (DHPM) at different pressures and passes on particle size distribution, soluble solids content, pH and color of goji juice, mango juice and carrot puree were studied. The results showed that DHPM reduced the particle size of the samples significantly ($p < 0.05$). pH and total soluble solids content of samples varied greatly depending on the DHPM treatment parameters. For color analysis, DHPM treatment at higher pressure was beneficial to color improvement, but the number of homogenization passes was not. The results provided a certain reference for the homogenization process in the processing of different fruit and vegetable juice/puree.

1 Introduction

Fruit and vegetable juices and their beverages are important food forms in our daily lives. They contain various nutrients such as protein, carbohydrates, cellulose, vitamins, organic acids and minerals can not only satisfy consumers' pursuit of taste, but also have health benefits. Thus the market demand and value are greatly increasing [1-2]. However, although the composition of the raw materials of fruits and vegetables after juicing is uniform, but some of the small "particle" components will still precipitate or become turbid due to gravity or the force between particles, which seriously affects the quality of the juice [3]. Dynamic high pressure microfluidization (DHPM) technology is a new type of high-pressure homogenization technology that can be used in fruit and vegetable juice production. It can achieve ultra-fine crushing of the cell walls of fruit and vegetable raw materials, simultaneously can homogenize and stabilize the fruit and vegetable juice complex system, improve the processing performance, nutritional properties and sensory quality of fruit and vegetable juices [4]. The important parameters of DHPM are homogenization pressure and homogenization pass cycles. According to existing reports, the effects of different treatment parameters of DHPM on different substrates are quite different [4-6]. Therefore, the purpose of this research is to take goji juice, mango juice and carrot puree as raw materials to study the effects of different pressures and passes of DHPM on the physical properties of the above raw materials, including particle size distribution, soluble solid content, pH and color analysis.

2 Materials and methods

2.1 Sample preparation

Using 80 mesh sieve, the goji (raw) juice (Provided by Bairui Source Goji Co., LTD, Ningxia, China), mango juice (Provided by Zhangpu County Dachuan Food Industry Co. LTD, Fujian, China) and carrot puree (Provided by Beijing Huiyuan Food and Beverage Co. LTD, Beijing, China) were filtered, leaving a small portion as control. The filtrated juice/pulp was homogenized by DHPM. Homogenization conditions are as follows:

Goji juice: homogenized at pressures of 50 MPa, 75 MPa, 100 MPa, 125 MPa, 150 MPa, and cycles of once, twice and three passes. Mango juice: homogenized at pressures of 50 MPa, 100 MPa, and cycles of once, twice and three passes. Carrot pulp: homogenized at 50MPa for one cycle.

2.2 Particle size and particle size distribution (PSD) determination

After DHPM treatment, the particle size distribution (PSD) of the juice was evaluated by LS 230 laser particle size analyzer (American Beckman Coulter Co., Ltd., Miami, USA), and the PSD was expressed as $D_{[4,3]}$. This analysis method also provides $D_{[3,2]}$, d_{10} , d_{50} and d_{90} . The particle size and distribution with a particle size of 0.4 μm to 2000.0 μm were calculated by measuring the scattered light intensity and scattering angle of the particles.

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2.3 Determination of total soluble solid

Total soluble solids (TSS) were determined using a digital refractometer (Abbemat 500 digital refractometer, Anton Paar Trading Co., Ltd., Shanghai, China) at 20 ± 1 °C, and results were expressed as °Brix.

2.4 Determination of pH

The pH values were measured by using a portable pH meter (Orion 3Star, Thermo Fisher Scientific Co., Ltd., America) at 25 ± 1 °C.

2.5 Color assessment

After the samples were processed, the color parameters L^* , a^* and b^* were immediately measured using a colorimeter (high-quality colorimeter NH300, 3NH technology Co., LD., Shenzhen, China). Where L^* represents the lightness values, and the higher the value, the greater the brightness of the sample; a^* represents the red-green values, the high positive value tends to be red, and the negative value tends to be green; b^* represents yellow-blue, the higher the positive value, the tendency toward yellow, and the greater the negative value, the tendency toward blue.

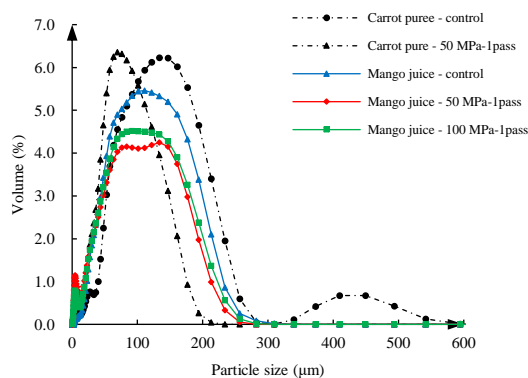
2.6 Statistical analysis

All samples were performed in triplicates. The results were expressed as mean \pm SD (standard deviation), and then subjected to statistical analysis of variance using SPSS 25.0 for Windows (SPSS Inc., Chicago, USA). Statistical differences were determined by one-way analysis of variance (ANOVA) with Duncan's post hoc test and the least significant differences ($p < 0.05$) were accepted among the treatments.

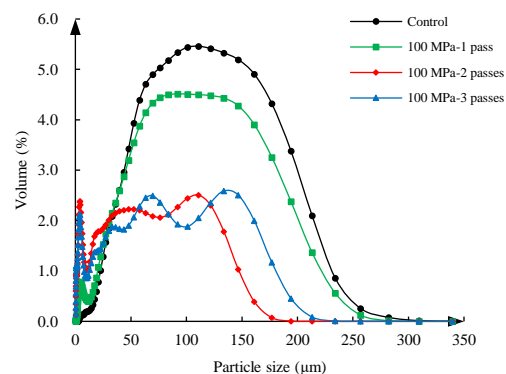
3 Results and discussions

3.1 Particle size distribution of goji juice, mango juice and carrot puree

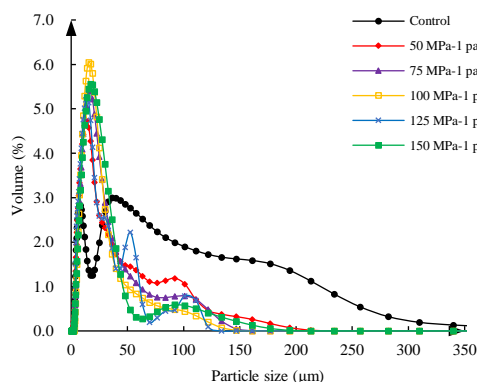
The PSD of goji juice, mango juice and carrot puree (Fig. 1) showed that the PSD of all samples became more uniform and smaller after DHPM. For the PSD of carrot puree moved from right to left (larger particle size to smaller particle size), while the PSD of goji juice and mango juice were mainly reflected in the change of the proportion of same sized particles. For different homogenization passes at the same pressure, it was



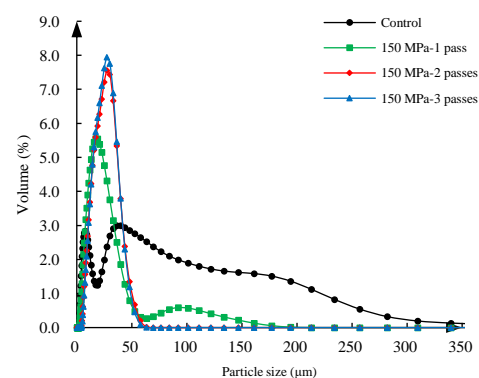
a. The PSD of mango juice and carrot puree under different pressure



b. The PSD of mango juice under different passes



c. The PSD of goji juice under different pressure



d. The PSD of goji juice under different passes

Fig. 1. Particle size distribution of goji juice, mango juice and carrot puree

Table 1 Effects of DHPM on particle size parameters of goji juice, mango juice and carrot puree

Samples	D _[4,3]	D _[3,2]	d ₁₀	d ₅₀	d ₉₀
Goji juice					
Control	52.868±2.42 ^d	14.405±0.05 ^d	5.322±0.02 ^a	30.642±0.60 ^e	142.102±4.21 ^d
50 MPa-1 pass	25.029±1.89 ^c	11.361±0.32 ^b	5.419±0.11 ^a	14.842±0.41 ^a	60.544±4.56 ^c
75 MPa-1 pass	23.542±0.27 ^{bc}	12.262±0.19 ^c	6.691±0.12 ^b	16.637±0.25 ^{bc}	48.047±2.29 ^b
100 MPa-1 pass	21.011±0.64 ^a	11.241±0.09 ^b	7.006±0.13 ^c	16.076±0.40 ^b	38.563±0.87 ^a
125 MPa-1 pass	20.597±0.81 ^a	10.526±0.16 ^a	5.455±0.07 ^a	14.182±0.29 ^a	46.028±2.18 ^b
150 MPa-1 pass	22.390±0.46 ^{ab}	14.218±0.29 ^d	6.666±0.11 ^b	16.973±0.40 ^c	38.464±0.69 ^a
150 MPa-2 passes	23.668±0.43 ^{bc}	15.814±0.29 ^e	10.133±0.09 ^d	22.531±0.45 ^d	38.712±0.69 ^a
150 MPa-3 passes	23.902±0.59 ^{bc}	18.713±0.28 ^f	10.832±0.14 ^e	22.941±0.63 ^d	38.342±0.94 ^a
Mango juice					
Control	98.713±1.12 ^e	60.756±0.23 ^e	32.474±0.43 ^d	89.063±0.74 ^e	181.103±2.12 ^e
50 MPa-1 pass	75.484±0.25 ^c	7.276±0.17 ^c	5.591±0.07 ^b	65.293±0.19 ^c	161.484±0.75 ^c
100 MPa-1 pass	81.753±0.25 ^d	11.483±0.14 ^d	7.165±0.06 ^c	72.107±0.08 ^d	167.635±0.75 ^d
100 MPa-2 passes	34.802±0.31 ^a	3.557±0.1 ^b	1.443±0.03 ^a	16.494±0.37 ^a	103.260±0.76 ^a
100 MPa-3 passes	41.927±0.04 ^b	3.004±0.08 ^a	1.233±0.01 ^a	18.099±0.05 ^b	127.716±0.10 ^b
Carrot puree					
Control	121.822±0.79 ^b	65.108±0.26 ^b	41.209±0.39 ^b	109.481±0.08 ^b	206.820±0.83 ^b
50 MPa-1 pass	75.777±0.03 ^a	44.367±0.15 ^a	25.421±0.12 ^a	70.110±0.37 ^a	134.912±1.14 ^a

Notes: different letters indicated significant difference at the same column ($p < 0.05$).

found that the homogenization passes once for goji juice was the best homogenization cycle, while pass twice for mango juice. In conclusion, the PSD of different substrates will have two types of situations : one was that the PSD moved in parallel from the larger particle size to the smaller particle size, in which case the large particles became smaller particles; the other was that the PSD moved from the left and right directions to the direction of the largest peak in the middle, in which case the larger particles were broken into smaller particles, simultaneously the smaller particles were slightly aggregated and became slightly larger particles than the original small particle size, caused the volume percentage of medium-sized particles increased, forming a relatively uniform particle dispersion system. Among the three different raw materials, goji juice showed the greatest degree of cell fragmentation, which may be because the cell tissue of goji juice belongs to soft tissue compared with mango juice and carrot puree, which is easy to be destroyed.

For goji juice, within the range of 50 MPa ~ 125 MPa, $D_{[4,3]}$ decreased with the increase of pressure, and the increase of the number of homogenization cycles had little influence on the particle size of goji juice. To mango juice, the particle size under 50 MPa was smaller than 100 MPa, and the particle size under 2 and 3 passes of homogenization were smaller than 1 pass. The $D_{[4,3]}$ was more influenced by the larger particles, while the $D_{[3,2]}$ was more influenced by small ones [7]. Hence, the above results indicated that DHPM treatment has a significant

effect on larger particles in goji juice, mango juice and carrot puree compared to smaller particles. The results of $D_{[3,2]}$, d_{10} , d_{50} and d_{90} were consistent with the PSD (Table 1).

3.2 Total soluble solids content in goji juice, mango juice and carrot puree

The influences of DHPM on TSS of goji juice, mango juice and carrot puree were shown in Fig. 2. After DHPM, the TSS of goji juice and mango juice were decreased, while the TSS of carrot puree was increased.

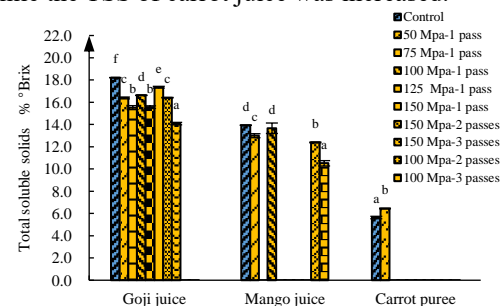


Fig. 2. Total soluble solids content in goji juice, mango juice and carrot puree

The chemical components in various fruits and vegetables were quite different, therefore the effect of DHPM on different fruit and vegetable juice substrates were also different. The decrease of the TSS in the juice may be attributed to the release of insoluble solid particles,

the denaturation of enzymes, or loss of the components that constitutes soluble solid in the juice during processing, which leads to the decrease of TSS [8-9].

3.3 pH values of different fruit and vegetable juices/purees

The pH effected by DHPM are shown in Fig. 3. For carrot puree, the pH value was not affected by DHPM at 50MPa. However, for goji juice and mango juice, the pH values were varied with treatment conditions. This may be due to the different degree of force provided by different treatment pressures of microfluidizer.

3.4 Effect of DHPM treatment on color of goji juice

Good color is one of the important qualities of fruit and vegetable juices and its beverages. However, the color of fruit and vegetable juice products is likely to change during production and storage, which affects its quality.

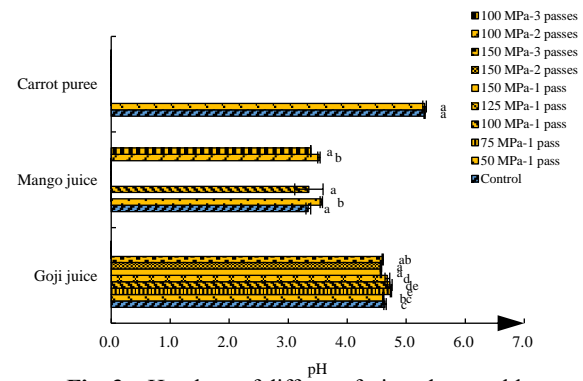


Fig. 3. pH values of different fruit and vegetable juices/purees

The effect of DHPM on the color of goji juice was shown in Table 2. When the goji juice was treated at 50 MPa and 150 MPa for one pass, the L^* , a^* , b^* values were significantly higher than the control ($p < 0.05$), indicating that the color of the goji juice after DHPM was more bright, red and yellow. The reason may be that DHPM can promote the release of pigment substances in goji juice. The ΔE (total color difference) was significantly higher than the control when the sample was treated at 150 MPa and one pass, indicating that the color changes were obviously. Besides, as the number of homogenization cycle increases, the L^* , a^* , b^* and ΔE all tend to be smaller values.

Table 2 Effect of DHPM treatment on color of goji juice

Processing conditions	L^*	a^*	b^*	ΔE
Control	47.871±1.09 ^b	21.201±2.63 ^a	23.677±1.77 ^a	41.332±0.71 ^a
50 MPa-1 pass	52.042±0.09 ^c	26.593±0.12 ^b	30.496±0.15 ^b	42.754±0.06 ^a
150 MPa-1 pass	54.039±3.42 ^c	32.948±0.97 ^c	46.798±5.76 ^c	53.489±1.87 ^c
150 MPa-2 passes	45.463±1.03 ^{ab}	26.019±2.37 ^b	31.980±1.76 ^b	48.019±1.03 ^d
150 MPa-3 passes	43.617±0.03 ^a	20.90±0.20 ^a	28.582±0.06 ^{ab}	45.953±0.08 ^b

Notes: different letters indicated significant difference at the same column ($p < 0.05$).

4 Conclusion

Under the same treatment conditions, DHPM has different effects on the PSD, TSS and pH of different fruit and vegetable juice substrates. The results show that DHPM can effectively reduce the particle size of goji juice, mango juice and carrot puree. The effect of DHPM on TSS and pH varied with different treatment conditions. Regarding to color, DHPM was helpful to improve the color of goji juice, but the increase in homogenization passes was not good for color retention. Therefore, it was recommended to select the treatment parameters that can reach the best characteristics of different raw materials in actual production.

Acknowledgement

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