

Studies on the Mechanical Properties of Vegetables Processed by High Pressure

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Abstract. It is a new technology to process and preserve fresh vegetables by high pressure processing (HPP). However, the qualities and texture of vegetables may sometimes be affected by HPP, and it is difficult to appraise the quality of processed vegetables. In this paper, the mechanical properties of samples before and after HPP were tested by PC-control Electronic All-purpose Tester, the equations of their stress-strain curves had been fitted. The conclusion showed that appraising vegetable quality by mechanical ways was an applicable method compared with food judges' degustation. Moreover, the solution of CaCl_2 (0.8%) was used to improve the qualities of vegetables after HPP, the result was ideal. The study has great significance of appraising the vegetable quality and improving the quality of vegetables processed by HPP. [The Journal of American Science. 2005;3(1):61-64].

Keywords: mechanical properties; vegetables; stress-strain; the solution of CaCl_2 ; HPP

1 Introduction

High Pressure Processing (HPP) is a new technology. To process and preserve fresh vegetables on high pressure began in 1914 (Xu, 2003). Processing vegetables on high pressure is a kind of ultra high hydrostatic pressure treatment at more than 100 Mpa (less than 100°C), to make protein denaturalize, enzyme inactivate and microorganism die, in order to keep vegetable fresh. In contrast to other methods, HPP offers several advantages: reduced process times; minimal heat penetration/heat damage problems; freshness, flavor and color are well retained; there is no vitamin C loss, and functionality-alterations are minimized compared with traditional thermal processing (CHEFTEL, 1995; WILLIAMS, 1994; Kloczko, 1996; Arroyo, 1999). Therefore, more and more people pay more attention on the technology (Fresher Under Pressure News, 2000).

On the other hand, HPP can affect the vegetables' qualities, because the tissues of vegetables are so tender that they can be easily damaged to make them soften. Therefore, at present, how to decrease the damage and how to improve their qualities after HPP is an impending problem to be solved

In this work, in order to decrease the damage on high pressure, garlic-stem, as an example of vegetables, was soaked in the solution of CaCl_2 (0.8%) for thirty

minutes before HPP. At the same time, the mechanical characteristics of garlic-stem before and after HPP were tested. The results showed that soaking in the solution could improve vegetable qualities effectively. Moreover, the conclusion demonstrated that appraising vegetable qualities by mechanical ways was a useful method compared with food judges' degustation.

2 Materials and Methods

2.1 Preparation of the samples

The garlic-stems were purchased in local supermarket and were absorbed in prime condition. After they were selected (chosen those whose texture and diameter were even and color was emerald green), they were washed by flowing tap water. Then, they were cut into sects which were 30 centimeters long. According to the experimental design, samples were divided into three groups: untreated samples (contrasts); samples prepared for HPP; samples soaked in the solution of CaCl_2 (0.8%) for thirty minutes prepared for HPP.

2.2 Instruments and Equipments

PC-control Electronic All-purpose Tester (HL-100, Hua Long Testing Instrument Factory, Shanghai, China) can test the nonmetal materials' mechanical properties. High Pressure Equipment (DL700-0.55 \times 1.5, Da Long Ultra High Pressure Equipment Factory, Shanghai, China) has a vessel capacity 350 ml, maximum pressure

of 700 MPa. Pressure is increased within 2 min and released within 0.5 min. Other common tools: Vacuum Packer, electronic balance, beakers, measuring cylinders, vernier calipers, knife, etc.

2.3 Experimental Procedure and Methods

All the samples were vacuumed and sealed with plastic bags, the samples for HPP were sealed twice in order to be isolated from the pressurization medium (oil). The sealed samples were respectively processed at 300 MPa; 400 MPa; 500 Mpa (10 min) at ambient temperature. Then, the mechanical characteristics of the samples were tested by the Tester, at the same time, the stress-strain curves were drawn by the software Hltest. In order to obtain the exact value, the samples were tested three times, the final value is average one.

3 Results and Discussions

3.1 The mechanical properties of contrast

Figure 1 was the typical stress-strain curve of fresh garlic-stem. It was composed of two segments, **oa** and **bc**. That **oa** segment was straight showed that elastic deformation had taken place in this period, its equation was linear equation (Table 2, contrast oa). In general, the fresh garlic-stem is very fragile, thus, its yield and maximum force are lower (Table 1), and there were one or two critical points (Figure 1, point b). That **bc** segment was curve showed that Not only elastic deformation, but also plastic deformation had taken place, and the shape of curve **bc** indicated that plastic deformation is primary. Its equation was a trinomial equation.

Table 1. The mechanical characters of samples

Samples	Max tensile force (N)	Yield Force (N)	Extensibility (mm/10N)	Modulus of elasticity(Mpa)	Maximum Strength (Mpa)	Yield point (Kpa)	Maximum extensibility(%)
300MPa	28.31	13.06	1.96	19.71	1.64	722.81	27.33
400MPa	28.52	14.56	2.23	17.67	1.81	866.49	28.09
500MPa	33.49	21.16	2.42	14.49	1.83	914.42	34.14
Contrast	25.91	9.96	2.36	11.09	1.17	455.83	23.71
300MPa-cl	25.83	14.78	2.81	15.02	1.89	912.79	21.45
400MPa-cl	22.08	14.02	1.95	21.44	1.58	698.25	15.84
500MPa-cl	25.675	14.15	2.38	14.45	1.55	792.75	26.39

—cl—samples soaked in the solution of CaCL₂ (0.8%) for thirty minutes before HPP

Table 2. Equations of samples' stress-strain curves

Samples	Segment	Equation	Freedom	RE
contrast	Oa	y=4.4286*x-0.4762	4	0.6901
contrast	Bc	y=0.0014*x ³ -0.1377*x ² +4.8658*x+14.9052	6	0.9542
500MPa	Oa	y=-0.0005*x ⁴ +0.0221*x ³ -0.2146*x ² +2.0783*x+0.3714	10	0.8759
500MPa-cl	Oa	y=4.3042*x+1.4556	4	0.8275
500PM-cl	Ab	y=0.0002*x ³ -0.0406*x ² +2.9031*x+32.0351	7	0.7837

RE—Residual Error (RE<1) (Zhang, 2000) RE=(∑(y_i-f(a, x))²)^{1/2} (i=1-n)

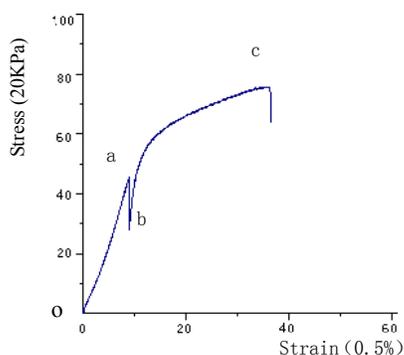


Figure 1. Typical stress-strain curve of contrast

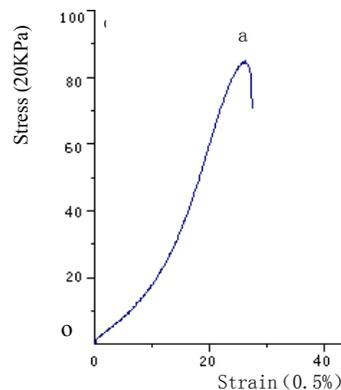


Figure 2. Stress-strain curve of sample after HPP (500 MPa)

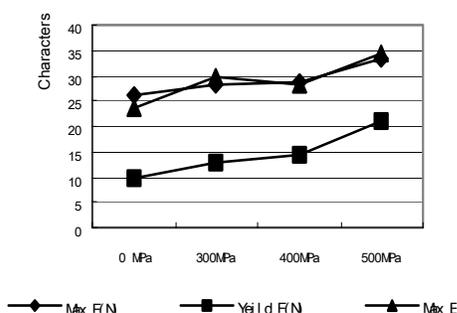


Figure 3. Relationship of pressure and mechanical characters

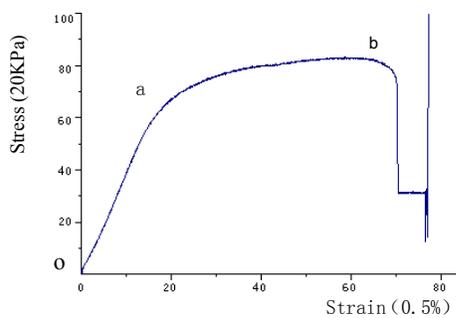


Figure 4. Stress-strain curve of soaked sample after HPP (500 MPa)

3.2 The mechanical properties of samples after HPP

HPP can destroy the vegetable tissues to some extent, so as to affect its surface and texture (Prestamo, 1998; Xu, 2004). The experiments demonstrated the viewpoint. After HPP, great changes had taken place, the value of samples' parameters were almost increased, especially Max tensile force, Yield Force and Max Extensibility (Table 1), moreover, the figures and equations of their stress-strain curve were widely divergent (Figure 2)

Although the mechanism that how HPP affects vegetables has not been clear, According to the change of the samples' mechanical characteristics after HPP, we can deduce that HPP made vegetable' inner structure compact, factional water effused, brittleness decreased, toughness increased. Therefore, it wasn't easily snapped, we got the above experimental results naturally.

Pressure's influence on vegetables was obvious.

The more the pressure was, the higher the influence was (Figure.3), this was not our expectation, and so we must take active action to solve the problem. On one hand, we should protect vegetable from damaging at least under high pressure; On the other hand, HPP combining with other methods was necessary and effective to decrease the pressure's damage.

3.3 The mechanical characteristics of soaked samples

Soaking green vegetables in solution of CaCl_2 (0.8%) can not only enhance their rigidity, but also keep their green color (Yao, 2000). The mechanism is: The Ca^{2+} ions can pass through vegetable's surface and penetrate, so as to enhance its rigidity. This change can prevent the tissues from damaging under high pressure. Our experiments showed that the soaked samples' mechanical parameters after HPP had restored, most parameters are similar to the contrast sample's (Table.1);

Furthermore, their stress-strain curves and equations are similar, too (Figure 4, Table 2). Therefore, we can conclude that soaking the samples in the solution of CaCl_2 (0.8%) can effectively improve the garlic-stem quality and overcome the disadvantage brought about by HPP. Moreover, the conclusion demonstrated that appraising vegetable qualities by mechanical ways was scientific to the traditional one (food judges' degustation) which has much more subjective factors.

Take into account of the preserving purpose, cost and quality of products, we suggest that the rational technology is: soaking the samples in the solution of CaCl_2 (0.8%) for thirty minutes before HPP, then processing them under 300MPa for ten minutes at ambient temperature.

4 Conclusion

(1) Fresh garlic-stem is fragile, elastic and tasty. Because of its soft tissues, HPP can easily affect its quality.

(2) After HPP, the mechanical characteristics of the samples have changed, all the parameters have grown up to a degree, especially Maximum Force, Yield Force and Maximum Extensibility.

(3) Before HPP, soaking the samples in the solution of CaCl_2 (0.8%) for thirty minutes can highly improve the garlic-stem quality and overcome the disadvantage brought about by HPP.

(4) Take into account of cost and quality of products, our experiments showed that the practicable technology is: soaking the samples in the solution of CaCl_2 (0.8%) for thirty minutes before HPP, then processing them under 300MPa for ten minutes at ambient temperature.

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