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# Effect of Processing Method on Change of Water Soluble Dietary Fiber of *Fagopyrum tataricum*

D. E. Kim, B. G. Lee, C. H. Park, W. S. Kang

**Abstract**: Seed, stem and sprout of *F. tataricum* were separately milled using the ultra fine mill under the same condition to investigate the effect of roasting or extruding on the particle size, microstructure and water solubility of dietary fiber. The mean particle size of MR (roasting) is increased in stem and sprout, and that of ME (extruding) is increased in seed, compared to that of control. The microscopic views of seed show that control has the spherical shape but ME the larger and irregular shape, and those of stem and sprout show that control has the needle like shape but ME more rounded shape. Water solubility index of ME is much higher than that of control or MR in seed, stem and sprout. It shows that seed, stem and sprout are damaged more in extruding than in roasting, and the starch and cell wall structure must be destroyed to change the water insoluble dietary fiber into the water soluble dietary fiber.
**Keywords:** Twin Screw Extruder, Ultra Fine Mill, Water Solubility Index, *Fagopyrum tataricum*

## Introduction

Recently the physiologically active components of buckwheat have been known and so buckwheat is widely used as health food (Park et al., 1999). Buckwheat contains a large amount of rutin, a kind of flavonoid, as well as vitamin $B_1$ and vitamin E. It is known that buckwheat decreases the permeability of blood vessel and controls the high blood pressure and sclerosis of arteries (Kwak et al., 2004). Now *F. esculentum* and *F. tataricum* are edible in buckwheat (Park et al., 2004).

*F. tataricum* has been used as oriental medicine and health food in China and India from ancient time. Park et al. (2004) reported that the rutin content of seed in *F. tataricum* is 1469.8 mg/100 g and 60 times higher than that (22.6 mg/100 g) of seed in *F. esculeotum*. Especially *F. tataricum* is a valuable medicinal plant which can be used as a raw material of oriental medicine or health food, because rutin is contained in flower, leaf, stem and root as well as seed.

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Even though in seed rutin is contained mostly in bran, bran is removed during milling, because bran as well as stem and sprout composed mainly with fiber contain much amount of the water insoluble dietary fiber and can not be digested by human, when milled using the current technologies, such as flint-stone, pin or Hammer type mill (Bonafaccia. et al., 2003a, Bonafaccia. et al., 2003b).

Natural plants, which contain the water insoluble fiber of more than 60%, are not edible (Khang et al., 2002). Therefore, nano processing technology, which can mill water insoluble natural resources to colloidal particle which is soluble in water, is necessary. Particle sizes of nutrients and fragrance in natural resource are 1~100 ㎛, but natural resource must be milled to smaller than 10 ㎛ to extract easily these effective components. Also, the milling technology to mill under low temperature is necessary to keep the natural fragrance of raw materials (Kang, 2004).

In USA and Germany, hot melt extrusion (HME) has been studied to make water insoluble dietary fiber of natural resources soluble in water. Extrusion using high temperature, high pressure and high shear strength can change the physical, chemical, nutritional and physiological characteristics of natural resource (Thava et al., 2002). Also, if water insoluble dietary fiber is extruded, much part is changed into the water soluble, and the physiologically active components in fiber can be extracted more by disrupting the cell wall structure (Hwang et al., 1994). Roasting is a process, which can preserve the color and fragrance of raw material. During roasting, the content of water soluble component is increased by degradation, synthesis or condensation (Park et al., 1993; Park et al., 2002). If natural resource is milled using the ultra fine mill after roasting or extruding, some of water insoluble resources can be changed into the water soluble through the breakdown of cell wall structure (Kang, 2004).

Therefore, if roasting or extrusion is used with ultra fine mill, natural resource can be milled into ultra fine flour, preserving the natural fragrance. The flour can be dissolved easily in water and drunk like coffee or tea. Also, these technologies can be applied to develop a lot of new health foods (Kang, 2004).

In this study the seed, stem and sprout of *F. tataricum* were separately milled to increase the water solubility with the ultra fine mill after roasting or extruding, and the particle size, microstructure and water solubility index were investigated.

## Materials and Methods

### 1. Materials

Seed, stem and sprout of *F. tataricum* (KW44, Japna), which was grown in Kangwon National University in 2004, were donated from the plant genetic resource laboratory. The materials were dried in a far infrared ray dry oven (HKD-10, Korea Energy Technology, KOREA) at 105℃ for 24 hours and cooled in a desiccator and weighed. The moisture content of seed, stem and sprout is 14.31, 7.38 and 7.35%, respectively.

### 2. Roasting

Seed was roasted at 160℃ for 1 hour, using a far infrared ray roaster (MK-2, Korea Energy Technology, KOREA), and stem and sprout were roasted at 80℃ (Fig. 1).

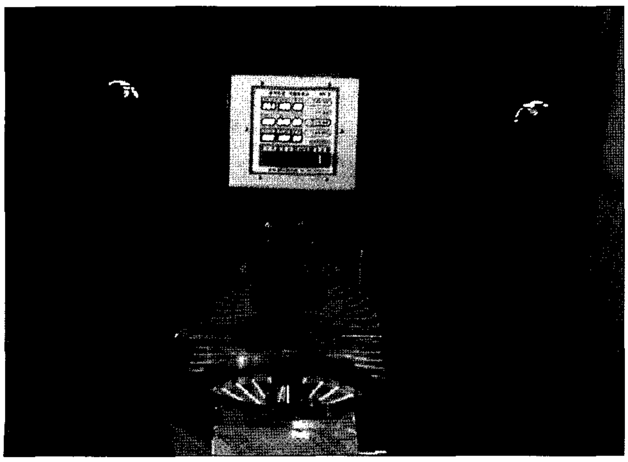

**Fig. 1 Far Infrared Ray Roaster.**

### 3. Extrusion

Extrusion cooking of *F. tataricum* was carried out in a co-rotating and intermeshing twin screw extruder (STS-32, HANKOOK E.M Ltd., Korea), of which the ratio of barrel length to diameter is 32:1 and the screw diameter 32 mm. The temperature of 8 to 4 section was kept to 180/150/120/100/90℃, respectively, with electrically controlled heaters on the barrel. The extruder was operated at a screw speed of 400 rpm (Fig. 2).

### 4. Ultra fine milling

*F. tataricum* was milled at a feed rate of 100 m/s using a ultra fine mill (HKP-05, Korea Energy Technology, KOREA) and then the particle size, microstructure and water solubility index were analyzed (Fig. 3).

### 5. Particle size analysis

After milling, the particle size was measured, using a particle size analyzer (Mastersizer-2000, Malvern Ins. Ltd, U.K.). The particle size distribution was expressed as the percentage of total volume.

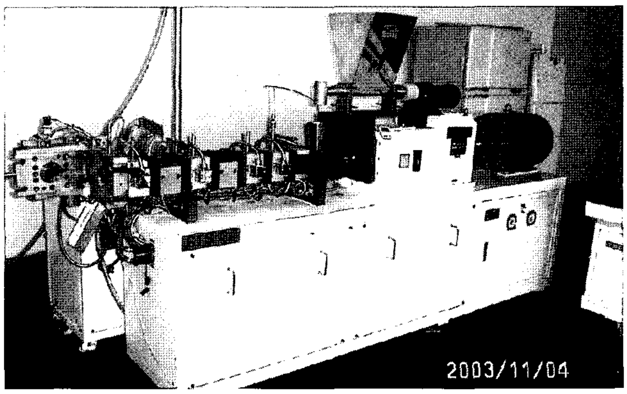


**Fig. 2 Twin Screw Extruder.**

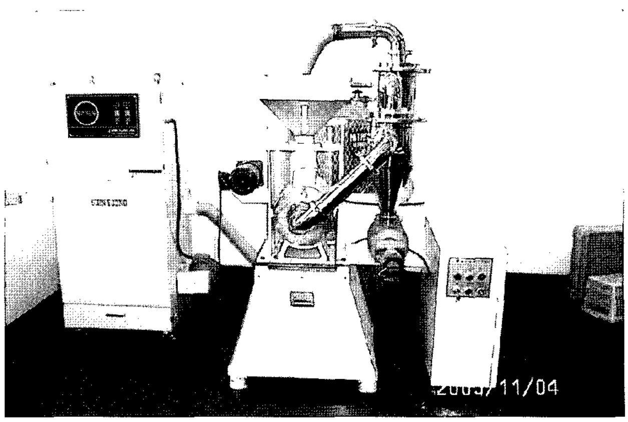

**Fig. 3 Ultra Fine Mill.**

### 6. Microstructure analysis

Scanning electron micrographs were taken to check the microstructure of milled particle. Samples were photographed at x500, x2000 using a field emission scanning electron microscope (S4300, HITACHI, JAPAN).

### 7. Water solubility index (WSI)

WSI was determined in triplicate using the method of Anderson et al. (1969). One gram of ultra fine milled sample was suspended in 20 ml of distilled water at room temperature for 30 min, gently stirring during this period, and then centrifuged at 2000 g (14520 rpm) for 10 min. The supernatant was decanted into an evaporating dish of known weight. The WSI is the weight of dry solid in the supernatant expressed as a percentage of the original weight of sample.

$$WSI(\%) = \frac{Weight\ of\ sediment}{Weight\ of\ dry\ soled} \times 100$$

## RESULTS AND DISCUSSION

### 1. Particle size analysis

Table 1 and Fig. 4 to 6 show the particle size distribution of seed, stem and sprout, which were milled into ultra fine flour after roasting (MR) or extruding (ME).

The mean particle size is the smallest in the control of seed and the largest in the MR of stem. The particle size of ME is increased compared to that of control in seed which has the high content of starch, but decreased in stem and sprout which include a large amount of fiber com-

**Table 1 Particle size analysis of *Fagopyrum tataricum***

| | | Particle diameter (㎛) | | | Specific Surface Area ($m^2/g$) | Mean Particle Size (㎛) |
|---|---|---|---|---|---|---|
| | | d10 | d50 | d90 | | |
| Seed | Control | 2.43 | 8.99 | 25.67 | 1.34 | 11.90 |
| | MR | 2.63 | 10.61 | 31.10 | 1.25 | 14.08 |
| | ME | 4.70 | 20.00 | 48.28 | 0.67 | 23.89 |
| Stem | Control | 3.11 | 19.90 | 69.08 | 0.84 | 34.21 |
| | MR | 4.64 | 30.24 | 125.99 | 0.61 | 54.61 |
| | ME | 2.38 | 14.14 | 40.08 | 1.17 | 18.21 |
| Sprout | Control | 1.90 | 10.16 | 36.93 | 1.39 | 15.42 |
| | MR | 2.13 | 10.88 | 44.50 | 1.30 | 22.17 |
| | ME | 2.85 | 11.21 | 28.47 | 1.18 | 13.68 |

* MR : Roasting, ME : Extruding

* d10 : Particle diameter at 10% of the volume distribution
d50 : Particle diameter at 50% of the volume distribution
d90 : Particle diameter at 90% of the volume distribution

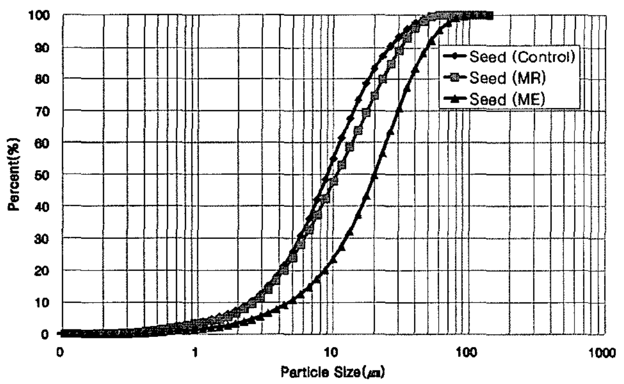


**Fig. 4 Cumulative distribution of control, MR and ME in seed.**

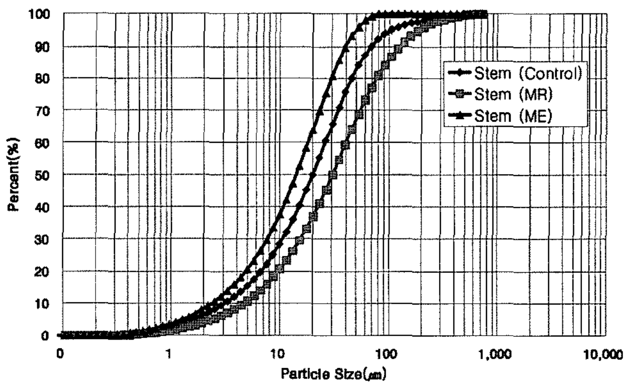


**Fig. 5 Cumulative distribution of control, MR and ME in stem.**

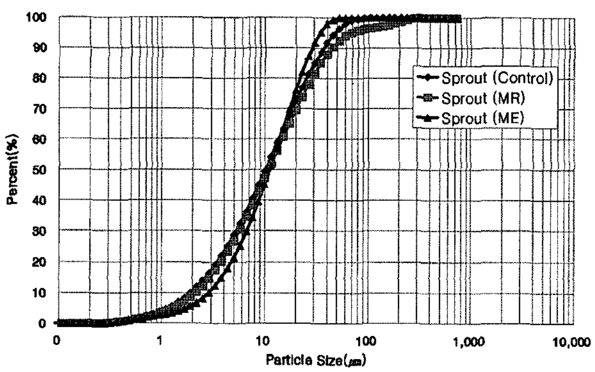


**Fig. 6 Cumulative distribution of control, MR and ME in sprout.**

pared to seed (Zemnukhova et al., 2004; Zheng et al., 1998). However, the mean particle size of MR is increased in seed, stem and sprout, compared to that of control. The specific surface area is decreased in seed, stem and sprout except for that of MR in sprout, as the mean particle size increases. The differences in the mean particle sizes of flours are related to differences in the pre-treatment before milling. All pre-treated samples subjected under the same milling condition have exhibited different particle sizes. It implies differences in the characteristics of the pre-treated samples. In other words, samples having different characteristics behave differently under the same milling condition and result in flours with different particle sizes.

The content of starch is higher in seed, compared to that of stem and sprout (Zemnukhova et al., 2004; Zheng et al., 1998), and the crystalline region of starch is irreversibly broken and disintegrated to form gel by the thermal degradation of extrusion process. During cooling process some parts of the crystalline structure of amylose are recrystallized by retrogradation but the stringy amylopectin is not and forms a rigid and brittle material (Fringant et al., 1996). Therefore, extrusion makes ME have the bulkier and weaker structure compared to control and MR, and so the mean particle size of ME in seed may be increased compared to that of control.

**2. Microstructure analysis**

Fig. 7 to 9 show the microscopic structures of control and ME of seed, stem and sprout. The microscopic struc-

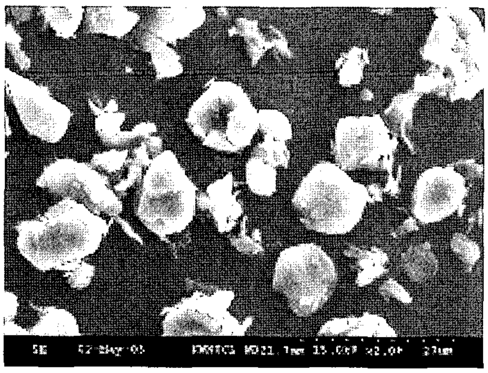

**Fig. 7-a Scanning electron microscopy image of control in seed (×2000).**

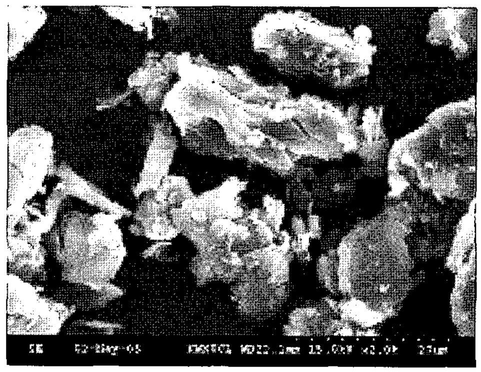

**Fig. 7-b Scanning electron microscopy mage of ME in seed (×2000).**

**Fig. 8-a Scanning electron microscopy image of control in stem (×500).**

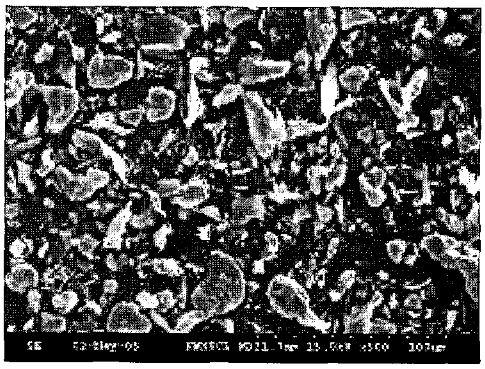

**Fig. 8-b Scanning electron microscopy image of ME in stem (×500).**


Fig. 9-a Scanning electron microscopy image of control in sprout (×500).

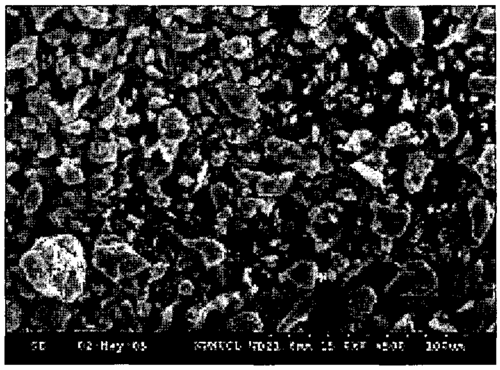


Fig. 9-b Scanning electron microscopy image of ME in sprout (×500).

tures of MR look similar to those of control and are not included in this paper. Fig. 7-a shows that the microscopic structure of control has smooth surface and spherical shape of particles. However, that of ME shows irregular shape of particles (Fig. 7-b). The particle size is much larger than that of control. It may be caused by the disruption of the crystalline structure of starch by gelatinization in extruding. In stem and sprout that of control shows needle shape of particles. The microscopic structures of ME show irregular shape of particles but more rounded shape of particles, compared to those of control (Fig. 8 and 9). Stem and sprout, which contain a large amount of water insoluble fiber compared to seed, have the stronger cell wall structures than seed, which contains a large amount of starch (Zemnukhova et al., 2004; Zheng et al., 1998). So even though control is milled using the ultra fine grinder, the cell wall structure of control may not be broken fully by milling and control may form a lot of needle shape of particles. However, in ME the cell wall structure is destroyed by high temperature, high pressure and high shear strength during extruding. Thus, ME may be more easily milled and form more round shape of particles.

**3. Water solubility index (WSI)**

Fig. 10 to 12 shows WSI of control, MR and ME of seed, stem and sprout. WSI is the highest as 26.65% in control of sprout, but after processing the highest as 46.56% in ME of seed. The decreasing order of WSI in control is sprout>stem>seed. After processing that of MR is the same as that of control but that of ME is seed>sprout>stem. WSI of MR is increased, compared to that of control, but the difference is less than 2%. However, WSI of ME is increased much, compared to that of control, and the difference is about 37% in seed,.

If starch is thermally degraded at high temperature, starch is easily dissolved even in cold water by the increase of water solubility of starch. Also, if the cell wall structure of fiber is disrupted by extruding, more water soluble components in cell wall are exposed by the disintegration of the cell wall layers. If milled after extruding, some part of water insoluble fiber can be milled into the colloidal particle, which is easily dissolved in water. By above reasons WSI

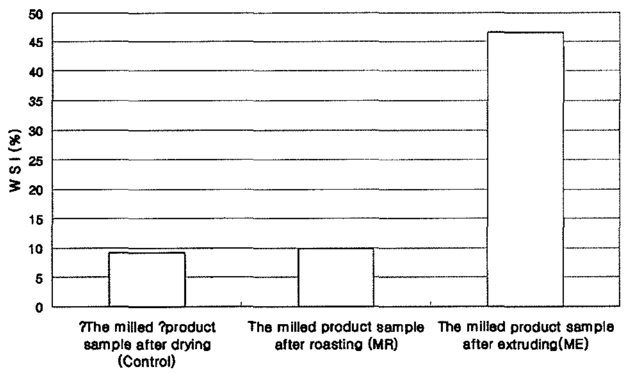


Fig. 10 Water solubility index of seed.

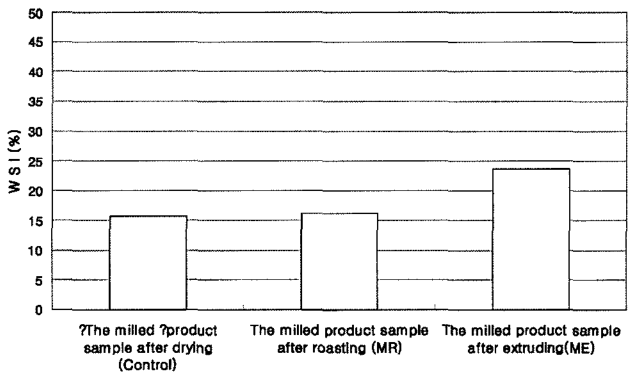


Fig. 11 Water solubility index of stem.

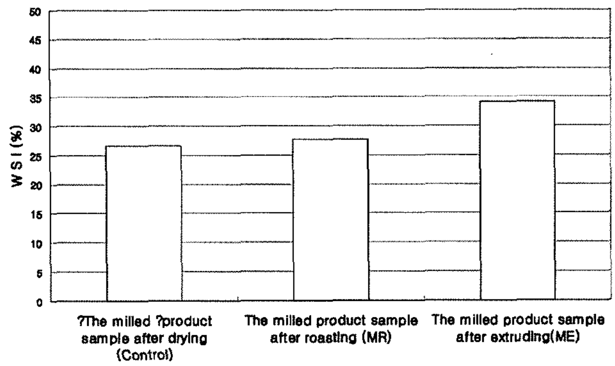


**Fig. 12 Water solubility index of sprout.**

of ME may be the highest.

## Conclusions

The characteristics of ultra fine powder milled after roasting or extruding *F. tataricum*, which is composed with seed, stem and sprout, are as follows.

1. The mean particle size of MR is increased in stem and sprout, compared to that of control. The mean particle size of ME is increased in seed, but decreased in stem and sprout, compared to that of control.
2. The microscopic views of seed show that control has the spherical shape but ME the larger and irregular shape, because the crystalline structure of starch may be disrupted in extruding. Those of stem and sprout show that control has the needle like shape but ME more rounded shape, because the crystalline structure in cell wall is damaged in extruding, and more easily broken in milling.
3. Water solubility index of MR is almost same as that of control, but that of ME is much higher than that of control in seed, stem and sprout. It shows that seed, stem and sprout are damaged more in extruding than in roasting, and the starch and cell wall structure must be destroyed to change the water insoluble dietary fiber into the water soluble dietary fiber.

This study shows that if *F. tataricum*, which contains the high content of water insoluble dietary fiber, is processed using the twin screw extruder and the ultra fine mill, the destruction of the crystalline structures of starch and fiber by the extruder and the powderization to the colloid particle size by the ultra fine mill can increase the content of water soluble dietary fiber, and these technologies can be applied to increase those of other oriental medicinal plants like *F. tataricum*.

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