IJIE Int. J. Indust. Entomol. 37(2) 105-108 (2018)
ISSN 1598-3579, http://dx.doi.org/10.7852/ijie.2018.37.2.105

ISSN 1598-3579 (Print)
ISSN 2586-4785 (Online)

[Note]

Effect of pulverizing method on the particle size of matured silkworm powder

Su-Bae Kim[1], Kee-Young Kim[1], Sang-Deok Ji[1], Seong-Wan Kim[1], Nam-Suk Kim[1], You-Young Jo[1], Jong-Gil Kim[1], Young-Guk Kim[2], Hui-Yeon Koo[3], Hyung-Chul Moon[4], Young-Seek Seok[5], and Hyun-Tai Lee[6,*]

[1]*Department of Agricultural Biology, Sericultural & Apicultural Materials Division National Institute of Agricultural Science, Rural Development Administration Wanju-gun, Jeollabuk-do, Republic of Korea*
[2]*Herbal Crop Research Division, Department of Herbal crop Research, National Institute of Horticultural and Herbal Science, Rural Development Administration Eumseong, Chungcheongbuk-do, Republic of Korea*
[3]*Insect & Sericultural Research Institute, Jeollanamdo Agricultural Research and Extension Service, Jangsung-gun, Jeollanam-do, Republic of Korea*
[4]*Agricultural Research and Extension Services Sericulture and Entomology Experiment Station, Buan-gun, Jeollabuk-do, Republic of Korea*
[5]*Gangwon Province Agricultural Product Registered Seed Station, Chuncheon 200-150, Korea*
[6]*Biopharmaceutical Engineering Major, Division of Applied Bioengineering, College of Engineering, Dong-eui University, Busan, Republic of Korea*

Abstract

Recently matured silkworm powder was developed by RDA. In this study, the effect of pulverizing method on the particle size of matured silkworm powder was examined. FESEM was performed to observe the morphology and to measure the particle size of silkworm powder. Particle morphology of air-jet mill pulverized powder was round and smooth, however, those of roller-mill and hammer-mill pulverized mature silkworm was more harsh and square. Particle size was varied with pulverizing technique as follows; 1.1 μm (air-jet mill), 10 μm (roller mill), and 120 μm (hammer mill), respectively. A proximate analysis results of air-jet mill powder showed that crude protein, crude lipid, crude fiber, and ash was 73%, 12%, 1.95%, and 3.4%, respectively. According to our results, air-jet mell technique might be used to make a tiny matured silkworm powder.

Int. J. Indust. Entomol. 37(2), 105-108 (2018)

Received : 28 Aug. 2018
Revised : 10 Dec. 2018
Accepted : 13 Dec. 2018

Keywords:
matured silkworm,
pulverization method,
FESEM,
particle size

Introduction

Several years ago, people could not considered matured silkworm(MS) as a food resource because silk gland becomes too hard to eat and digest. Recently, Ji *et al.*, (2015) developed cooking technique to make MS edible. Pulverizng mill is used to obtain MS powder after cooking. Generally, frictional heat during the pulverizing process might be increase the sample which could be possible to decompose heat-sensitive components (Song and Park, 1997; Kang 1995). Therefore, when selecting a grinder, we should be consider the size and characteristics of the raw material, grinding temperature, and the purposed particle size.

Hammer-mill has been used to pulverize cooked MS. However, it is not convenient for making silkworm powder.

***Corresponding author.**
Hyun-Tai Lee
Biopharmaceutical Engineering Major, Division of Applied Bioengineering, College of Engineering, Dong-eui University, Busan 47340, Republic of Korea
Tel: +82-51-890-1534 / FAX: +82-505-182-6871
E-mail: htlee@deu.ac.kr

For example, silkworm powder sticks to hammer mill rotor and mesh because contains a large amount of protein and fat (Ji *et al*., 2017). In the present study, various pulverizing mill has been examined to make a silkworm powder and observed and measured its shape and size through electron microscope. Proximate analysis also carried out after pulverizing.

Materiasl and Methods

Test silkworm

Test silkworm variety was Yeonnokjam which makes a pistachio colored cocoon (Kang *et al*., 2011). Firstly silkworms were reared with mulberry leaves in the National Institute of Agricultural Science (Wanju-gun, Korea) in 2017. MS was steamed at 100°C for 120 min using an electric pressure free cooking machine (KumSeong Ltd., Bucheon, Korea), followed by freeze-dried using a freeze-drier (FDT-8612; Operon Co., Ltd., Gimpo, Korea) at -50°C for 24 h.

Preparation of MS powder

The MS samples were pulverized using a hammer-mill (Fig. 1. (a), (b) , HM001, Korean PulverizingMachinery Co. LTD., Incheon, Korea), roller-mill (Fig. 1. (c), (d), Duksan Co., Ltd., Siheung, Korea), and air-jet mill (Fig. 2. (e), (f), DCH-500D, Duksan Co., Ltd., Siheung, Korea). The operation condition of hammer-mill and roller-mill is 400 rotor revolution per minute (RPM) at room temperature. MS sample was pulverized 10 times with hammer-mill and roller-mill. The operation condition of air jet-mill is 4,000 RPM with liquid nitrogen as a refrigerants to keep the sample temperature (Table 1).

Field emission scanning electron microscope observation

Field emission scanning electron microscope (FESEM; US-70, Hitachi, Japan) was used for observe the pulverized MS powder and measure the particle diameter. The magnitude of microscope is x600. The pulverized with hammer-mill MS powder coated with platinum. The platinum sputter-coating thickness was about 100 nm. The pulverized with roller-mill and air-jet mill MS powder was spread on distilled water on a slide glass and observed with FESEM.

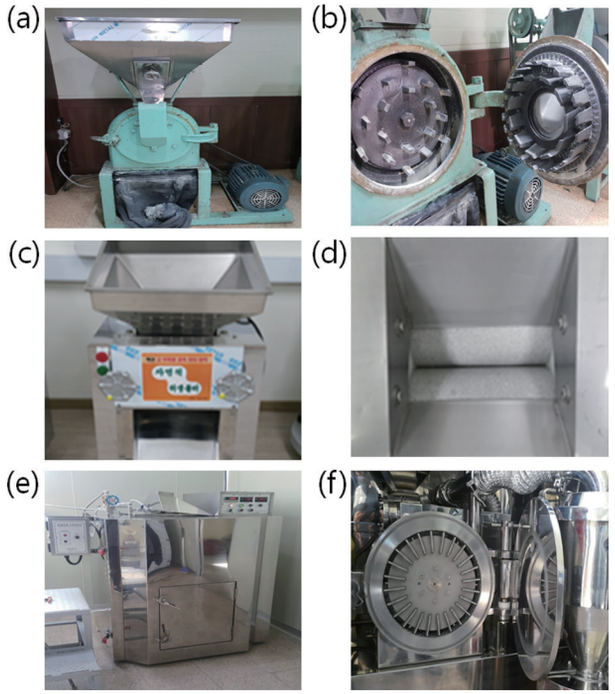

Fig. 1. Photographs of pulverizing machine; hammer mill (a), hammer part of hammer mill (b), roller mill (c), roller part of roller-mill (d), air-jet mill (e), inside appearance of air-jet mill (f).

Results and Discussion

Recently several researchers reported MS has a good bioactivies such as increased healthspan, preventing parkinson's disease, anti-melanogenic activity (Nguyen *et al.* 2016; Ji *et al*., 2016; Choi *et al*., 2017; Yun *et al*., 2017;

Table 1. Optimal pulverization condition, pulverizing time, and loss ratio using roller-mill and air-jet mill.

pulverization method	Sample temperature (℃)	Rotor revolution (per/min)	Time required per kg (min)	Loss ratio(%)
Roller mill pulverization	Room temperature	400	3.6 ± 0.41	8.8 ± 1.32
Air-jet mill puverization	-95	4000	9 ± 0.21	1.1 ± 0.21

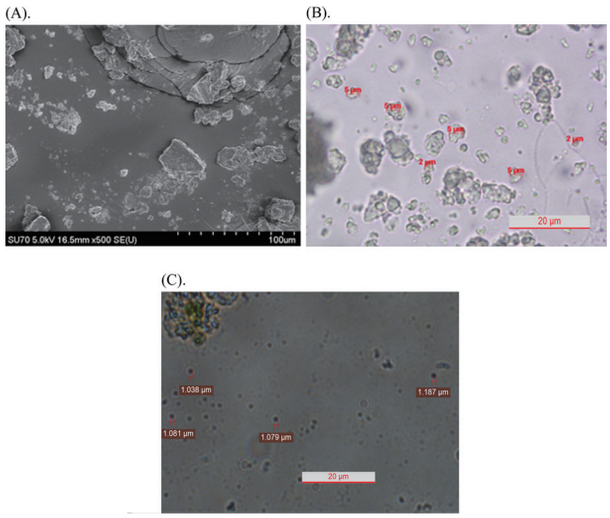

Fig. 2. Photographs of MS powder using field emission scanning electron microscope prepared by hammer-mill (A), roller-mill (B), and air-jet mill (c).

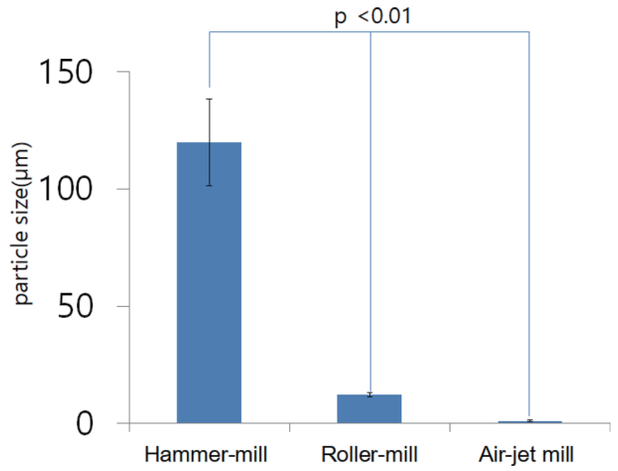

Fig. 3. Average MS particle size prepared by hammer-mill, roller-mill, and air-jet mill. Sample were analyzed by one-way ANOVA followed by DUNKAN test Different sample indicate significant differences at $p < 0.01$

Kim *et al.*, 2017). To increase the availability of MS powder as food resource, pulverizing technique should be developed. Fig. 2 showed photographs of MS powder prepared through hammer mill (a), roller mill (b), and air-jet mill (c). The shape of the MS pulverized by hammer mill was harsh and square, and the size looked uneven and different (Fig. 2(A)). The shape of MS powdered by roller mill showed more rounder than that of hammer mill one, but still harsh compared to air-jet mill one pulverized MS sample (Fig. 2(B)). Air-jet mill one showed the most rounder and even size distribution compared to hammer mill and round-mill ones.

According to manufacture of air-jet mill, rotor of air-jet mill rotates high speed over 4,000 rpm with frozen sample. At that time samples collide among them and result in fine powder. The pulverized one was obtained through center side of the rotor by centrifugal force.

Table 2 showed the pulverizing time and loss ratio of MS. The time to pulverize MS needs 3.6 min (roller mill) and 9 min (air-jet mill). The ross ratio of MS was 8.8% (roller mill) and 1.1% (air-jet mill), respectively.

Particle size and particle size distribution was observed and calculated using photographs of MS powder. As shown in Fig. 3, average particle size of air-jet mill one (1.1 μm) was smaller than that of hammer mill (120 μm) and roller mill (10 μm). During powdery process, hammer-mill and roller-mill generate heat and be stuck by pulverized MS.

Table 2 showed the results of proximate analysis. The amounts of water (H_2O) and crude fiber, and ash of MS powder made by hammer-mill, roller-mill, and air-jet mill were not significantly different among them. On the other, the abundant component and the second component showed significant different among them; crude protein of hammer mill one (66.12%) was significantly less than those of roller mill (73,13%) and air-jet mill (73. 00%). Crude lipid of hammer mill one (11.37%) was significantly less than that of roller-mill (14.05%).

Table. 2. The proximate analysis of MS powder with different pulverization mathods. Sample were analyzed by one-way ANOVA followed by DUNKAN test Different letter a, b, c indicate significant differences at $p < 0.05$ (mean ± STDE, %).

component	hammer mill	roller-mill	air jet-mill
H_2O	2.96±0.03^{a}	2.34±0.02^{a}	2.85±0.05^{a}
crude protein	66.12±0.34^{a}	73.13±0.50^{b}	73.00±0.42^{b}
crude lipid	11.37±0.11^{a}	14.05±0.065^{b}	12.03±0.08^{ab}
crude fiber	1.54±0.235^{a}	3.50±0.13^{a}	1.91±0.112^{a}
ash	3.57±0.05^{a}	2.78±0.03^{a}	3.38±0.04^{a}

Acknowledgment

This research was supported by the next-generation Bio-Green 21 Research and Development Project (project number: PJ01332401).

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