

## Effect of Physical Properties of Silkworm Pupae in Designing of Multi-Purpose Solar Tunnel Dryer

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### ABSTRACT

A study was conducted to determine the physical properties of silkworm pupae of different breed (PM X CSR<sub>4</sub> and PM X CSR<sub>4</sub>) required during designing of post harvest processing, transportation and storage equipment. The physical properties were measured at different breed, initial moisture content and weight of sample under open sun yard drying and solar tunnel dryer. The different treatment combinations of length, width, thickness, geometric mean diameter, sphericity, thousand pupae mass, surface area, volume and bulk density were linearly decreased with moisture content. The average length, width and thickness of fresh, sun dried and solar tunnel dried pupae were found to be 24.85, 21.05, 21.40mm, 10.04, 9.32, 9.98mm and 8.72, 7.14, 6.33 mm respectively. The average geometric mean diameter, sphericity, and thousand mass pupae values of fresh, sun dried and solar tunnel dried pupae were found to be 12.8, 11.25, 10.69 mm, 0.53, 0.51, 0.49, and 1171.5, 375.5, 378.12g respectively. The average surface area, volume and bulk density of fresh, sun dried and solar tunnel dried pupae were found to be 440.26, 340.97, 322.84 mm<sup>2</sup>, 878.10, 699.85 and 694.17 mm<sup>3</sup>, and 721.31, 234.01 and 234.78 kg/m<sup>3</sup> respectively.

**Key words:** Silkworm, Pupae, Post harvest processing, Solar tunnel dried

### INTRODUCTION

Silkworm pupae is not well known among consumers but it is an interesting by-product obtained after the extraction procedure of silk threads. The pupae, which are obtained after reeling the silkworm cocoons, are generally thrown away though they are very rich in amino acids, oil, carbohydrate and minerals. The large quantity of wastes that accumulates

in silk reeling process in India could be utilized as a high potential raw material for various industries including animal nutrition<sup>13</sup>. Dead pupae are highly perishable. Value addition to silkworm pupae can be enhanced by finding suitable preservation methods and by conversion of silkworm pupae into convenient processed products for wider market acceptability in different regions.

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In India, approximately 40,000 MT of silkworm pupae is produced through sericulture, per annum. Conventional method of drying and disposal of silkworm pupae cause environmental pollution besides loss of nutrients in them. Pupae and moths are used in preparation of medicines (vitamin- E), poultry food, oil extraction etc. Silkworm pupae have been found to be a rich source of protein. They are a good source of animal protein in place of fish meal in animal feeds. There is a need to tap the potentiality of silkworm pupae for socio-economic development of rural and urban population<sup>15</sup>. Currently two major types of commercial hybrids viz., CSR<sub>2</sub> X CSR<sub>4</sub> and PM X CSR<sub>4</sub> are reeled at reeling industries. Literature survey revealed that there are no comparative study for proximate analysis, amino acid and antioxidant for *Bombyx mori* pupae (after reeled) of CSR<sub>2</sub> X CSR<sub>4</sub> and PM X CSR<sub>4</sub> hybrid which can be used for poultry industry. Hence it was the major goal of this study to investigate if there is any difference in the physical properties and nutritional value of these two hybrids.

Physical properties of foods are essential parameters for food processing operations as well as for process design, modelling and optimization. The physical properties are importance for food processing and engineering<sup>3</sup>. Information on physical properties of agricultural products is needed in design and adjustment of machines used during harvesting, separating, cleaning, handling, drying and storing of agricultural materials and convert them into food, feed and fodder. The properties which are useful during design must be known and these properties must be determined at laboratory conditions. The geometric properties such as size and shape are one of most important physical properties considered during the separation and cleaning of agricultural grains. In theoretical calculations, agricultural seeds are assumed to be spheres or ellipse because of their irregular shapes<sup>10,11</sup>. Ahmadi and Mollazade<sup>1</sup> determined the physical and mechanical properties of funnel seed as a function of moisture content. They found that there was a parabolic mathematical equation

for sphericity, true density, and deformation on both seed length and width sections with changes of moisture content.

The application of physical properties such as shape which is an important parameter for stress distribution in materials under load is important in developing sizing and grading machines and for analytical prediction of its drying behaviour<sup>6</sup>. It is important to have an accurate estimate of shape, size, volume, density, surface area and other physical and mechanical properties that may be considered as engineering parameters for that product, when biomaterials are studied either in bulk or individually<sup>9</sup>.

### MATERIALS AND METHODS

Generally, Multi-end Reeling Machine (MRM) Unit with 100 kg cocoons consumption per day produces about 50 kg to 60 kg of wet pupae. Every day about 60 kg of wet pupae procured from reeling unit at Shidlagatta and Chintamani taluk to conduct the drying experiment (breeds of B<sub>1</sub>-multivoltine and B<sub>2</sub>-bivoltine). The outer skin removed dead pupae are collected by some small scale entrepreneurs called pupae collectors. The moisture content of the silkworm pupae was measured at the start and end of each run of experiments using a hot air oven method. Silkworm pupae were then spread in a thin layer on stainless steel wire screen trays and partially dried in sun from initial content about 70 % (w.b) to a moisture content of 60 % and 50 % (w.b). The partially dried pupae were weighed to a 10 kg and 15 kg in each tray and placed in solar tunnel dryer to conduct drying experiment (fig.3). The drying was started by 9.00 a.m. and discontinued at 4.00 p.m. for each day. The drying was continued on subsequent days until the desired moisture content of about 8 % (w.b) for silkworm pupae was reached. The physical properties such as length, width, thickness, geometric mean diameter, Sphericity, volume, surface area, thousand pupae mass and bulk density were measured before drying and after drying for both breed (B<sub>1</sub>-multivoltine, B<sub>2</sub>-bivoltine).

**Determination of physical properties:**

The average size of grains was determined by measuring three linear dimensions namely, length (L), width (W) and thickness (T) for 100 randomly picked grains. The vernier calipers (6 inch, Aerospace, Micro Precision Calibration Inc.) used for measurement was having an accuracy of 0.001 mm<sup>16</sup>. The geometric mean diameter (D<sub>g</sub>) of the grain was calculated by using the relationships given by Mohsenin<sup>9</sup>.

$$D_g = (LWT)^{1/3} \quad (1)$$

Where, D<sub>g</sub> is geometric mean diameter (m), L is the length (m), W is the width (m), T is the thickness (m).

The Sphericity (Φ) and grain volume (V) of grains were calculated using the relationship as suggested by Jain and Bal, 1997.

$$\Phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

$$V = \frac{\pi W^2 L^2}{6(2L-W)} \quad (3)$$

The surface area, S was also found by a relation suggested by Jain and Bal<sup>8</sup>.

$$S = \frac{\pi BL^2}{2L-B} \quad (4)$$

Where, S = Surface area

$$B = (W \times T)^{0.5}$$

Where, W is the width (m), T is the thickness (m).

The mass of one thousand pupae was manually counted and measured by using an electronic balance (Citizon, CG-203 model) with an accuracy of 0.001g<sup>4</sup>.

Silkworm pupae were filled into a container of known dimensions. The excess

was stroked off so that top surface was even.

The bulk density (BD) was determined according to Mohsenin<sup>10</sup> and Stroshine and Hamon<sup>14</sup>.

$$\text{Bulk density} = \frac{\text{weight of sample in container (kg)}}{\text{Volume of container (m}^3\text{)}} \quad (5)$$

**RESULTS AND DISCUSSION**

The linear dimensions of silkworm pupae namely length, width, thickness were measured. The average length of fresh, sun dried and solar tunnel dried pupae were found to be 24.85, 21.05 and 21.40 mm respectively. Whereas the average width of fresh, sun dried and solar tunnel dried pupae were found to be 10.04, 9.32 and 9.98 mm, respectively. It was also recorded the average thickness fresh, sun dried and solar tunnel dried pupae were found to be 8.72, 7.14 and 6.33 mm respectively. The moisture content has caused significant difference among the different dimensions of the silkworm pupae. The mass of 1000 pupae also increased with increase in moisture content. Similar observations were reported by several other workers who found that the principal dimensions (length, width, thickness and mean diameter) of seeds increased as seed moisture content was increased, (Deshpande and Ojha, 1993 for soyabean). The geometric mean diameter of fresh, sun dried and solar tunnel dried silkworm pupae were calculated. The average geometric mean diameters of fresh, sun dried and solar tunnel dried silkworm pupae were found to be 12.8, 11.25 and 10.69 mm, respectively shown in (Fig.2). It was evident from data that geometric mean diameter of silkworm pupae was higher for fresh because of moisture content, hence the geometric mean diameter increases with increase in moisture content.

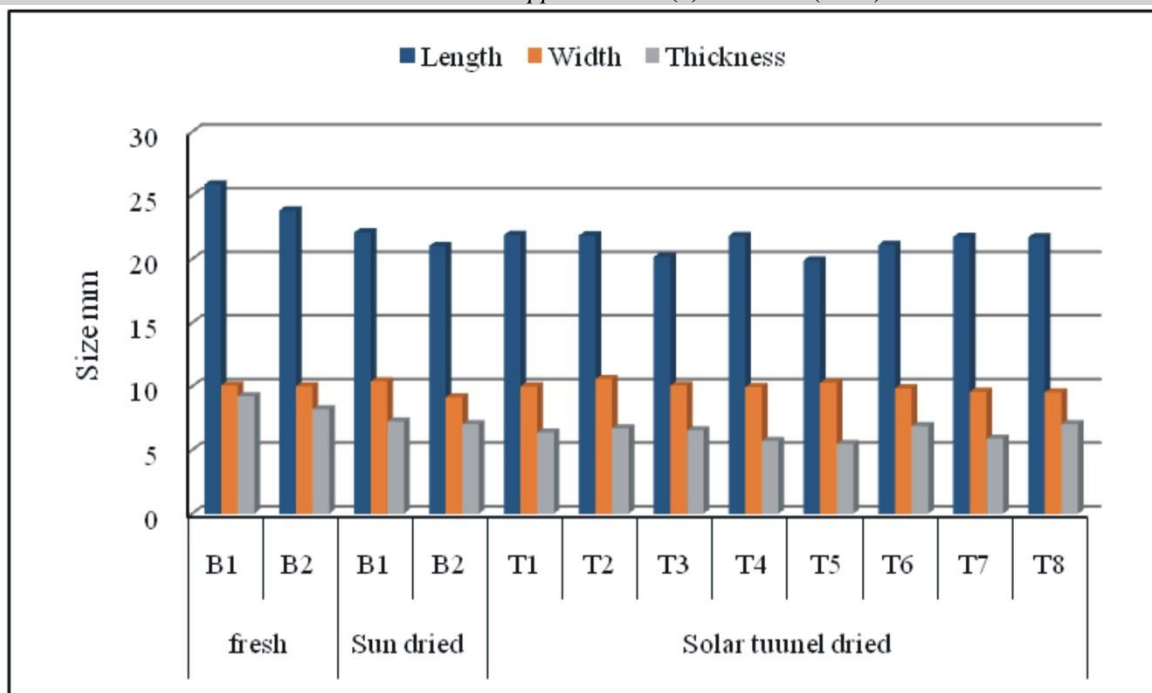


Fig. 1: Effect of drying on size of silkworm pupae

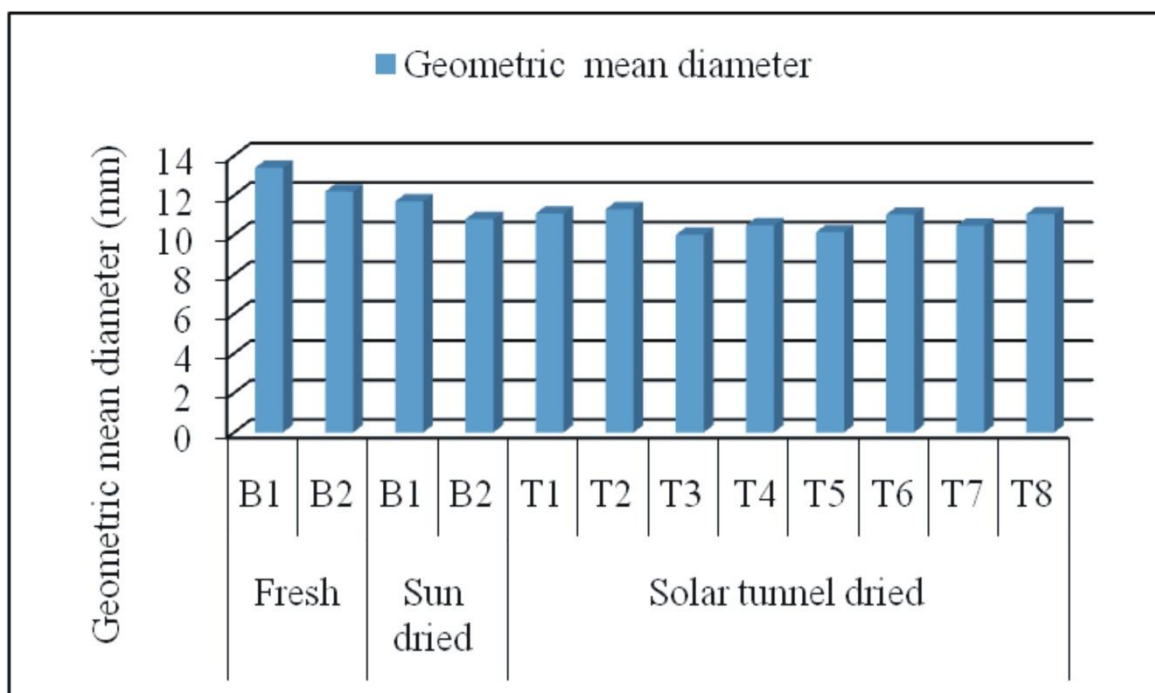


Fig. 2: Effect of drying on geometric mean diameter of silkworm pupae

The average sphericity values of fresh, sun dried and solar tunnel dried pupae were found to be 0.53, 0.51 and 0.49, respectively shown in (Fig.3). The increase in sphericity expected to roll rather slide on the surface and this is a property quite important in the design of hoppers<sup>2</sup>. The average thousand mass of fresh,

sun dried and solar tunnel dried pupae were found to be 1171.5, 375.5 and 378.12g, respectively shown in (Fig.4). It is obvious that the mass of most of the grains increases with an increase in moisture content of grains, because voids spaces inside grains gets filled with water.

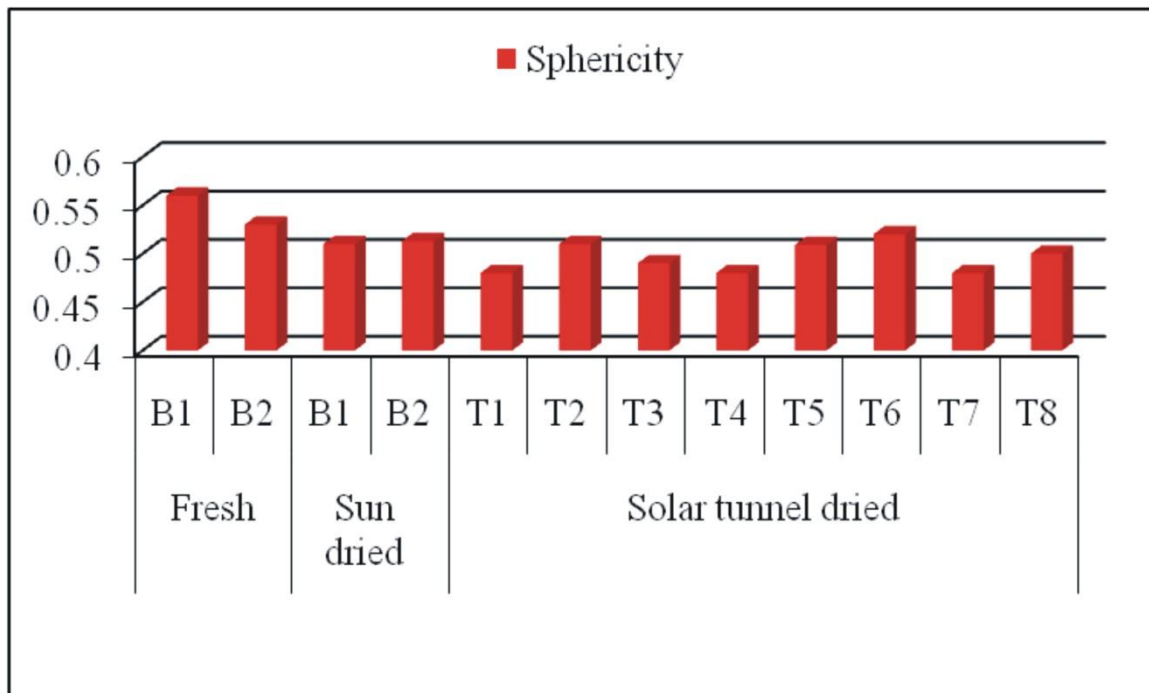


Fig. 3: Effect of drying on Sphericity of silkworm pupae

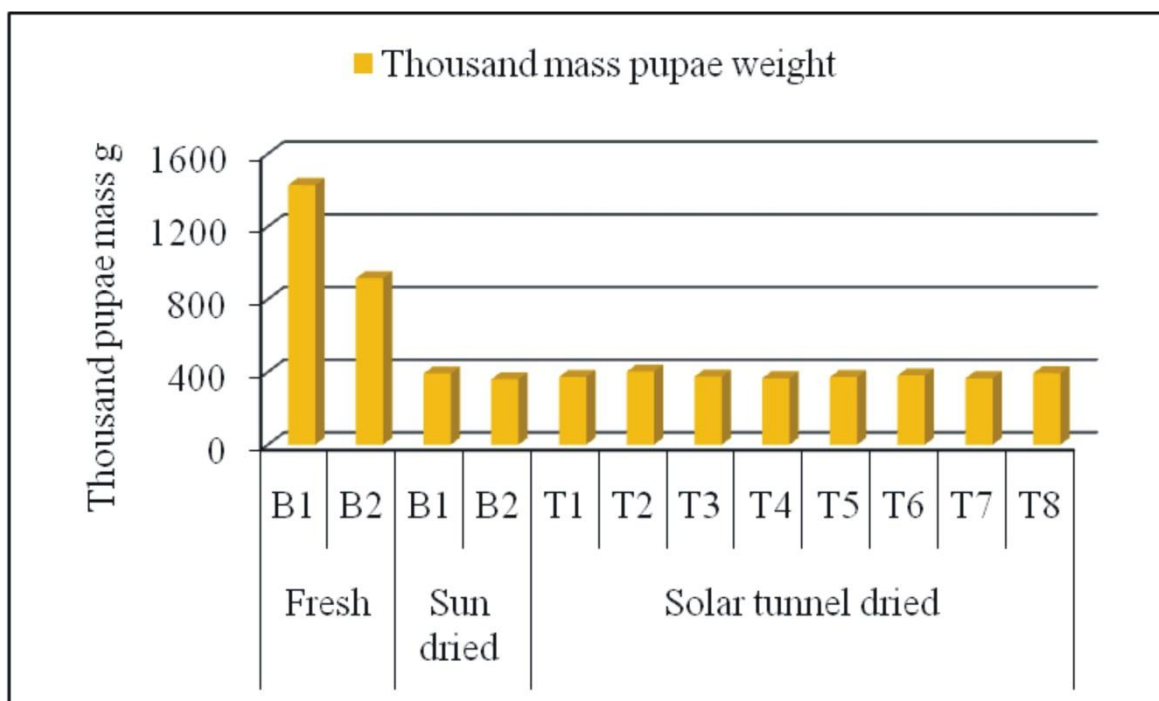


Fig. 4: Effect of drying on thousand pupae mass of silkworm pupae

The surface area, volume and bulk density of fresh, sun dried and solar tunnel dried silkworm pupae were calculated. The average surface area of fresh, sun dried and solar tunnel dried pupae were found to be 440.26, 340.97 and 322.84 mm<sup>2</sup> respectively shown in (Fig.5). The reduction of surface area was due to shrinkage of fleshy body of silkworm pupae due to moisture loss from the outer surface upon drying. The shrinkage is caused by particle slip into a more compact arrangement upon drying by the loss of water involved in pores of surface layer (Hasatani and Itaya, 1996). If surface area occupied is lowest by bulk pupae, it would also reduce the storage space, handling and transportation cost. The average volume of fresh, sun dried and solar tunnel dried pupae were found to be 878.10, 699.85 and 694.17 mm<sup>3</sup>, respectively shown in (Fig.6). The reduction in volume was due to moisture loss leading to shrinkage of pupae during the drying process. The moisture loss was found to be in the range of 10 to 60 per cent. This moisture loss was responsible for the significant volume reduction of pupae during drying macroscopically, water is involved in pores of solids so as to expand the aperture, and a decrease in the water volume reduces the volume of the pores or the apparent volume of the solid. Once again, the

shrinkage is caused by particles slip into a more compact arrangement upon drying<sup>7</sup>.

The average bulk density of fresh, sun dried and solar tunnel dried pupae were found to be 721.31, 234.01 and 234.78 kg/m<sup>3</sup>, respectively shown in (Fig.7). This could be attributed with the volumetric expansion was greater than mass of pupae. And during consolidation the resistance between pupae may have increased with moisture content as a result of increase in internal pressure. It was also understood if the body surface moisture absorptivity is high and a reducing effect of bulk density can be witnessed. However, the decrease in bulk density may not remain linear with further increase in moisture content it could start increasing with increased moisture content. For example, Singh and Goswami (1996) observed that the bulk density of cumin seed increased from 477 to 502 kg/m<sup>3</sup> with an increase in moisture content from 7 to 9.5% d.b. then decreased from 502 to 410 kg/m<sup>3</sup> with an increase in moisture content up to 22 % d.b. The bulk density of pupae is important in determining the capacity and load acting on drying bin, storage and transportation systems. The bulk density determines the overall dimension of deep bed drying bins hence for designing it is advisable to consider the highest bulk density of pupae.

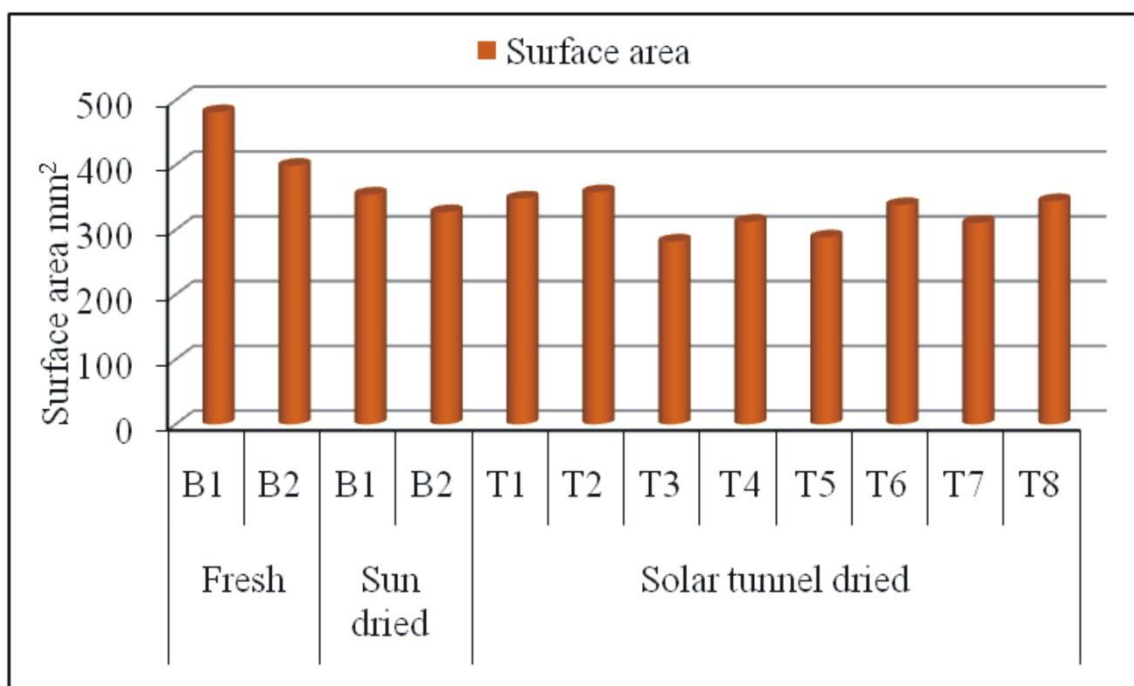


Fig. 5: Effect of drying on surface area of silkworm pupae

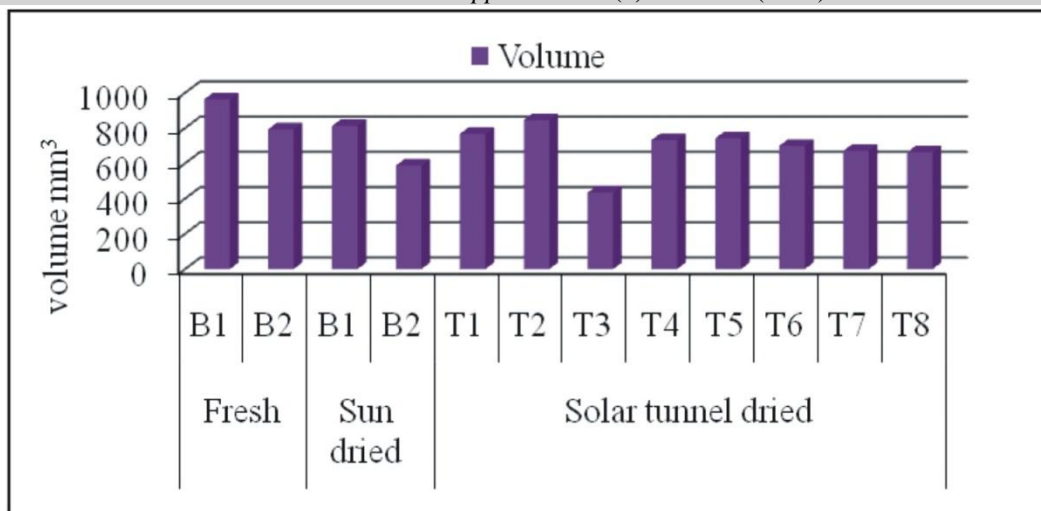


Fig. 6: Effect of drying on volume of silkworm pupae

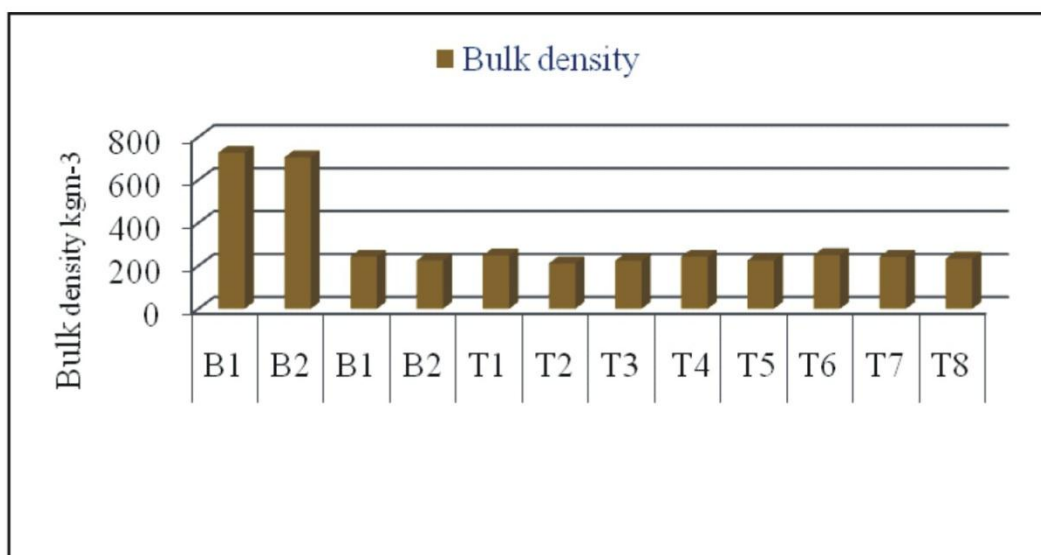


Fig.7: Effect of drying on bulk density of silkworm pupae

### CONCLUSION

The silkworm pupae dimensions like length, width and thickness decreased as drying proceeds, which was due to loss of moisture leads to shrinkage of pupae body. Silkworm pupae of surface area, volume and thousand mass pupae were decreased linearly as the seed moisture content reduce. The bulk density also decreased linearly with decrease in moisture level.

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