MARIGOLD PETAL THRESHING WITH OPEN VERSUS SECTORED ROTARY DRYERS

P. R. Armstrong, M. L. Stone, G. H. Brusewitz

ABSTRACT. *Marigold petals can be detached from flowers by tumbling while being dried in a rotary heated–air dryer. This study examined the effect of dryer diameter, RPM, airflow, and flower compaction on threshing petals from marigold flowers using two types of rotary dryers. A sectored rotary dryer was tested at three rotational speeds (2, 4, and 8 rpm) and two diameters (1.2 and 1.8 m). An open–chamber rotary dryer was tested with three levels of flower compaction (1.0, 1.5, and 2.0 X) and three airflows (4.3, 4.5, and 5.3 changes/min). Both the sectored and open chamber dryers performed well in drying and threshing petals from flowers. In most tests, more than 80% of the petals were threshed when their moisture dropped to less than 10%, i.e., within 20 to 24 h of drying.*

Threshing performance was different between the sectored and open dryer. The sectored dryer had a relatively large increase in the threshing rate after 10 to 15 h of drying while the open dryer's threshing rates remained fairly constant. The open dryer produced more threshed, high moisture petals. Threshed material from both dryers contained an insignificant amount of trash. The threshing characteristics for both dryer types were unaffected by changes in operating speed, amount of compaction, and airflow. However, by using higher compaction, the open dryer can thresh 50 to 100% more flowers.

Keywords. *Flowers, Marigold, Petals, Rotary dryer, Threshing.*

Plant materials contain a wide range of naturally occurring pigments that are a source for food and pharmaceutical colorants. Among the plant pigments, carotenoids constitute a major potential source of yellow, orange, and some red colors (McWilliams, 1989). Marigold flower petals contain the highest concentration of the xanthophyll group of carotenoids. In comparison, yellow corn and alfalfa contain xanthophyll in much smaller concentrations. Currently, the major use of marigold–derived xanthophyll is by the poultry industry for broiler skin and egg yolk coloration. Extensive research has been directed toward understanding how xanthophyll is metabolized by poultry and the factors influencing its effectiveness (Fletcher et al., 1978 and 1986; Janky et al., 1985; Papa et al., 1985; Allen, 1993; Hencken, 1992; Piccaglia et al., 1998). Studies of human health and carotenoids have also indicated lutein and zeaxanthin, both major constituents of xanthophyll, are helpful in preventing macular degeneration (Blumberg, 1997).

Article was submitted for review in April 2001; approved for publication by the Food & Process Engineering Institute of ASAE in December 2001.

Approved for publication by the Director, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma. This research was supported by a grant from the Oklahoma Center for Advancement of Science and Technology and the Oklahoma Agricultural Experiment Station.

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Rotary dryers are used for drying a wide variety of materials. The fundamental advantage of a rotary drying system when operated properly is uniform drying due to continuous tumbling and mixing of the product. Schofield and Glikin (1962) examined rotary drying of fertilizers. Kelly and O'Donnell (1977) determined residence times in a cascading dryer for small particles. Alvarez and Shene (1994) and Shene et al. (1996) studied volumetric heat transfer in a rotary dryer for soya, fishmeal, sawdust, and sand. Ramakumar et al. (1996) investigated rotary drying of rice in a sand medium to decrease drying time compared to conventional drying methods. Pelegrina et al. (1998) used a multiple stage rotary design for drying diced onions.

Research by Buser et al. (1999) determined moisture diffusion rates of marigold flowers. Petals dried more quickly than the receptacles and the differential drying rates were used to describe moisture conditions for optimal petal detachment during threshing. Britton (1999) built a plate thresher as a method for separating dried petals from partially dried flower receptacles using a reciprocating plate and a corrugated rubber, endless conveyor belt. The system took advantage of the differential drying rates between the petals and receptacles. Flowers with high petal moisture content (>20% MC) did not thresh well; a large percentage of the petals remained on the receptacle. Receptacle size, which changed with harvest date, also affected the amount of trash in the threshed petal material. The major disadvantage of this system was the requirement to accurately predict petal and receptacle moisture contents at the end of deep–bed drying and the time to transfer to the plate thresher. Armstrong et al. (2000) used a sectored rotary dryer that, in most cases, achieved good threshing efficiencies. Petals threshed well when the petal moisture content was reduced to below 12%. When the degree of threshing action was considered insufficient, increasing rotational speed or drum diameter

  ISSN 0883–8542

may be desirable. With its moisture reduced to less than 12%, the flower's bulk volume was reduced to approximately 25% of its original volume. This shrinkage in flower volume made it difficult to maintain uniform airflow distribution throughout the drying process.

Objectives

The objective of this research was to compare the effect of dryer diameter, RPM, airflow, and flower compaction on the threshing efficiency of two types of rotary dryers for threshing marigold flowers.

Rotary Dryers

A sectored rotary dryer, similar to the dryer previously used by Armstrong et al. (2000), was tested at higher rotational speeds and larger diameters. An open–chamber rotary dryer was tested with different amounts of flower compaction and airflows.

Sectored Dryer

The sectored rotary dryer used in this study was a version of the dryer described by Armstrong et al. (2000) modified to provide a larger diameter (fig. 1). The rotary drum was comprised of nine pie–shaped sectors; three 1.83–m diameter, three 1.22–m diameter, and three 1.22–m diameter unused sectors. The dryer was 0.31 m wide with the sides of the dryer made from 19–mm thick plywood. Steel angle was used for internal structural support. Eighteen–gauge sheet metal was used as dividers between the sectors.

A tubular air–distribution plenum (152 mm dia.) was placed in the center of the dryer. Side hatch access doors were used for filling and sampling flowers. Sheet metal collection funnels were made and attached to the ends of each sector to collect threshed petals and fine trash. Wire mesh (6.35 × 6.35 mm) was located between the end of each sector and funnel to separate the threshed petals from the receptacle as the dryer rotated. The end of each funnel had a cross–sectional area of 5806 mm^2. A small access hole was drilled in the funnel elbow to allow air velocity measurements. Nylon stockings were taped to the ends of the funnel to collect threshed petals. The combination of airflow and funnel angle prevented threshed petals from re–entering the sector after they had passed through the mesh and into the stocking.

A variable–speed drive motor and v–belt speed reduction system was used to rotate the dryer. The dryer frame was sized to elevate the drum to allow the collection bags to hang down and provide an open entrance to receive falling petals.

Open Dryer

The open rotary dryer consisted of a 1.2–m diameter internal drum, divided into three adjacent cylindrical compartments, surrounded by an external drum or enclosure (fig. 2). The three compartments were used to test different compaction levels of flowers. A section of the enclosure was removed and used to provide airflow path control. The basic concept of the dryer was that the internal drum could be entirely filled with flowers and rotated as air was forced through the flower mass. The enclosure would maintain airflow through the shrinking flower mass and rotation would be effective in petal removal.

Circular dryer components were constructed from 12.7–mm plywood. Pipe spacers evenly placed within the compartments separated the internal drum compartments. Perforated 18–gauge sheet metal, with 6.35–mm holes punched to provide 60% open area, was fastened to the outer edge of the internal drum. The perforated sheet metal acted as a screening device by allowing passage of petals but not receptacles. A door hatch was fabricated from the sheet metal for loading and emptying purposes. The enclosure diameter

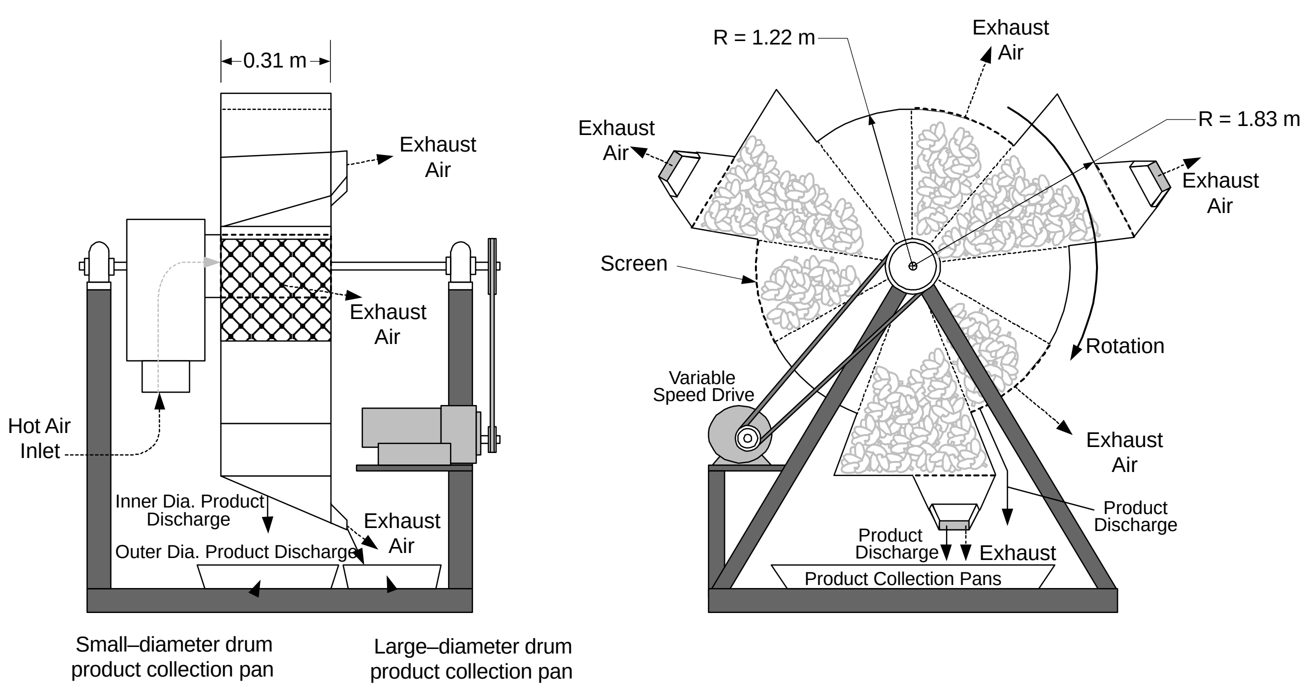

Figure 1. Sectored dryer.

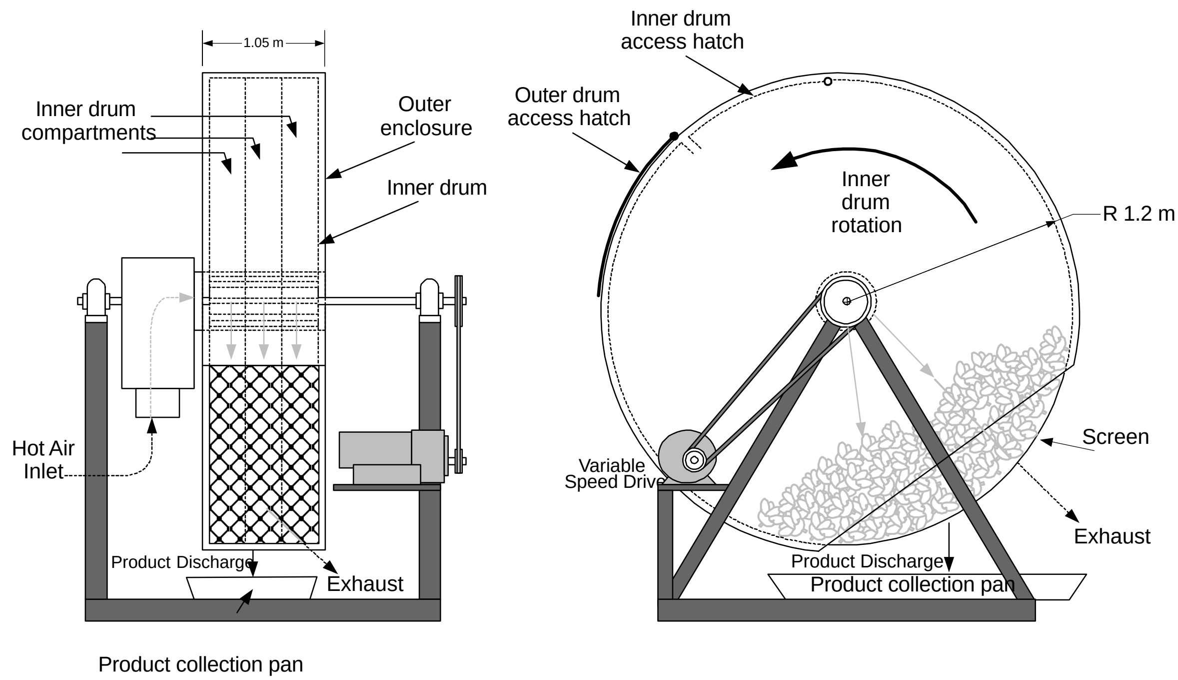

Figure 2. Open dryer.

was 25 mm larger than the internal drum diameter to provide a 12.7–mm clearance gap. The enclosure drum was covered with 20–gauge sheet metal except over the section opening.

The entire dryer assembly could be rotated about its plenum axis to allow top loading of flowers. The plenum blower and drive assembly were similar to the sectored dryer. Circular rubber air seals were used at the plenum–enclosure interface and straight rubber flap–seals were used at the enclosure and internal drum interface to prevent excessive air leakage. Seals around the section opening were adjustable to compensate for wear. Orientation of the section opening in the enclosure was set so that flowers would ride the internal drum, during rotation, at the same angle as the section opening, about 38° from horizontal. During drying, the compartments contained different compaction levels of flowers and created different air resistance. Therefore, moveable air diversion vanes were placed inside the plenum to control air distribution to each compartment. Monitoring and adjusting these vanes distributed airflow more evenly.

A steel angle structure supported the drum and enclosure and also provided drive and motor mounts. A chain drive and pulley system was used to transfer power to the drum axle. Petal collection boxes were fabricated from 12.7–mm thick plywood to collect petals from each compartment. A similar box was also made to fit snugly to the enclosure and internal drum to allow airflow to be measured and adjusted with the airflow vanes. Foam door seals were used to seal this second box to the enclosure and internal drum. Exhaust air was forced through this box and flowed out through 76.2–mm diameter, 65–mm long PVC tubes in the back of the box.

A blower and electrical resistance heater produced the drying air for both dryers. Drying air was routed to the dryers through insulated, 152–mm ID flexible plastic ducting equipped with a straight metal section to measure airflow. A pressure difference type (Annubar™, Dieterich Standard, a subsidiary of Rosemont Inc.) flowmeter calibrated for the metal tubing was used to measure airflow rates. Drying temperature was maintained at 60°C for both sectored and open dryer tests. A thermocouple was attached to the rotary dryer plenum and to the bed dryers' PID controller.

PROCEDURES

Marigold flowers (variety I822 and EI236, Resource Seeds, Gilroy, Calif.) were used in the drying studies. Flowers were planted on research plots at a commercial farm near Hydro, Oklahoma. Whole flowers that had well developed blooms were handpicked, placed into black polyethylene bags, and brought to the Biosystems and Agricultural Engineering Research Lab in Stillwater. They were stored from 1 to 8 days in a cooler at 7°C until 3 to 4 h before the beginning of the drying tests when they were brought out to ambient temperature of about 30°C. Sample lots of 100 flowers were taken just before each test to determine the dry weight of unthreshed petals and receptacles and the initial moisture contents. The initial dry weights were used to determine the percent of petals threshed by comparing them with samples taken during drying.

SECTORED DRYER TESTS

Since previous research by Armstrong et al. (2000) indicated that a 0.6–m diameter sectored dryer rotating at 1 rpm did not provide enough agitation for adequate threshing, this research was planned for larger diameters (1.80 and 1.2 m) and higher rotational speeds (2, 4, 8 rpm) for the sectored dryer. Tests were repeated at least twice (different flower harvests) for the same parameter conditions. A constant airflow was used for all tests and was set so that it provided 19 volume changes/min for both diameters.

Flowers were placed (loose–filled) into the dryer sectors for drying to start at 10 P.M. Flowers were left to dry overnight until 6 A.M. when samples were taken from each sector.

Samples were taken at 2–h intervals thereafter and consisted of 10 flowers from each sector. Threshed petal material was also collected from each sector at the same times. Samples were taken to the lab where they were separated into petal and receptacle components. Moisture contents of these components were determined by oven drying at 101°C for 24 h (*ASAE Standards*, 1999) and computed on a wet basis. The sample's initial dry mass and the dry mass at various drying periods were used to determine the percentage of petals that had been threshed. The percentage of petals threshed at any time period was defined as: %Petals threshed = 100 × (dry mass of petals actually threshed / dry mass of total petals available). Dry masses were computed from wet masses and moisture contents.

Total airflow was measured and adjusted as necessary at the sampling intervals. Airflow was also measured for each sector to ensure each sector was receiving the same airflow. Because angle of rotation influenced airflow to each sector, airflow was measured at the same point in rotation. Generally airflow remained well balanced to each sector but total airflow increased as flowers dried and thus was adjusted.

Open Dryer Tests

Open dryer test parameters were flower compaction level and airflow. Compaction levels were 1X, 1.5X, and 2X the loose fill mass. Flowers were hand–packed into the dryer. Compaction levels were determined by measuring the loose–fill mass for the 1X compaction and using this mass to determine the mass of flowers required for the other levels of compaction. A compaction level of 2X required careful attention to packing and was approaching the physical limit at which flowers could be hand–packed into the dryer. A single test was run with the three sections of the dryer filled at the three different compaction levels. Rotational speed of the dryer was held constant at 1/2 rpm for all drying tests.

Initial testing indicated that uniform airflow was difficult to adjust and maintain during the drying process. Listed values are average airflows over the duration of the drying test. Airflows were 4.30, 4.53, and 5.30 volume changes/min for the 1X compaction level. Three test runs were conducted using flowers from three different harvest dates. Each test consisted of three compaction levels at three different airflows.

Flowers were placed in the dryer in the evening and drying started at 10 P.M. Flowers were left to dry overnight until 6 A.M. when sample flowers were taken from each section. Samples were taken thereafter at 2–h intervals and consisted of 10 flowers from each section. Threshed petal material was also collected. Samples were processed the same as for the sectored dryer to obtain component moisture contents and percentages of threshed petals. Airflow measurements were recorded for each section and adjustments made when necessary to maintain a constant airflow through each section.

Results and Discussion

Rotary Threshing Action

The threshing action produced in the sectored dryer differed from that in the open dryer, although both rely on mechanical agitation of the flowers to detach petals. Flowers in the sectored dryer shrank as they dried allowing them to tumble over each other and slide from end–to–end which induced threshing. A larger diameter dryer created a longer travel distance and subsequently increased the kinetic energy imparted to the flowers as they collided with the ends of the sector. Increasing rotational speed increased the frequency at which these collisions occurred. The open dryer threshing action was different in that flowers primarily tumbled and impacted each other. At high moisture contents and compaction levels, flower movement was only slight, but as they dried and shrank there was more movement and kinetic energy imparted to the flowers.

Sectored Dryer

Overall, there was little or no difference in threshing between the two drum diameters of 1.2 to 1.8 m. Results show that about 80 to 90% of petals were removed within the first 20 h of drying for both diameters. Threshing characteristics for the 1.2–m diameter sectors are representative for both sector diameters although petal removal was somewhat faster for the larger diameter at greater rotational speeds. Typically threshing rates were low for the first 10 to 15 hours of drying before increasing significantly (fig. 3).

As the unthreshed petal MC dropped below about 20%, a rapid increase in the percentage of petals threshed occurred for both sector diameters (fig. 4). The percentage of petals threshed versus threshed petal moisture content for the 1.2–m dryer is shown in figure 5. The majority of the threshed petals (> 80%) had moisture contents of 10% or less.

Open Dryer

Unlike the sectored dryer where threshing increased exponentially especially after 10 to 12 h of drying, the percentage of petals threshed increased linearly for the open dryer (fig. 6). Higher airflows produced up to 90% petals threshed in 22 h while low – medium airflows had 35% less threshing. At 1.5X compaction the threshing results were similar while at 2X compaction, the threshing was equally high for all airflows.

Compared to the sectored dryer, the open dryer had greater percentages of petals threshed, especially above 15% unthreshed petal moisture content with little effect due to different airflows (fig. 7). Compared to 1X compaction the results at 1.5X were similar but at 2X there were about 10% less petals threshed at 20 to 60% unthreshed petal moisture content.

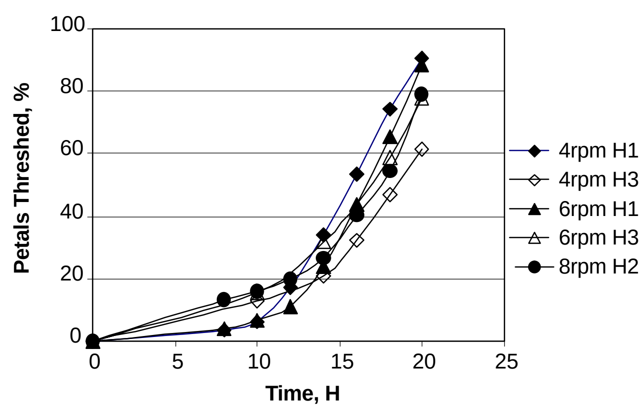

Figure 3. Percent of threshed petals vs. drying time for the 1.2–m diameter sectored dryer. Legend indicates rotational speed and harvest, respectively

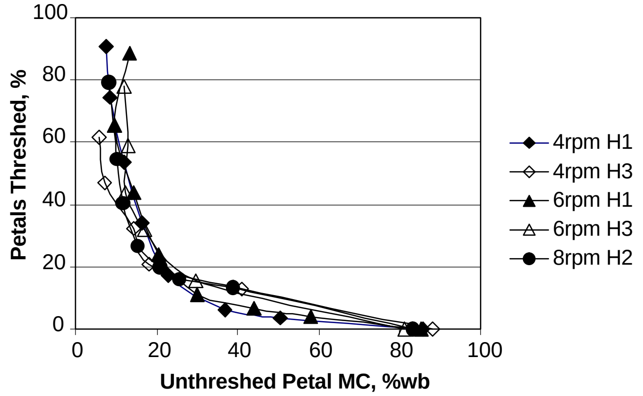

Figure 4. Percent of threshed petals vs. the unthreshed petal moisture content for the 1.2–m diameter sectored dryer. Legend indicates rotational speed and harvest, respectively.

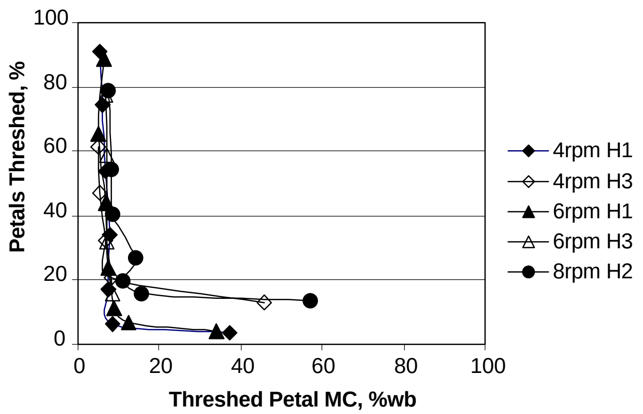

Figure 5. Percent of threshed petals vs. threshed petal moisture content for the 1.2–m diameter sectored dryer. Legend indicates rotational speed and harvest, respectively.

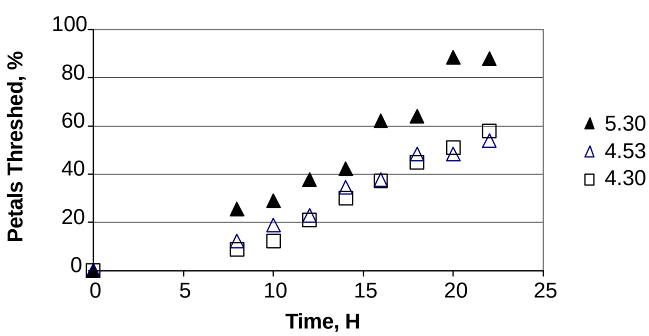

Figure 6. Percent of threshed petals vs. drying time for the open dryer at 1X flower compaction and three airflows (volume changes/min).

A major portion of the petals were threshed after they dried to below 10% MC but there was a significant portion (30 to 40% by weight) that had a moisture content above 20% MC (fig. 8). For the sectored dryer, this portion of higher moisture petals was 20% or less. This wet, threshed portion was evident during sample collection when a significant amount of petals with high moisture content were threshed early in the drying process. We suspect that some of the high moisture petals were threshed due to being pulled through the screen by the airflow seal rubbing against the screen. Compared to these results at 1X compaction, the data for

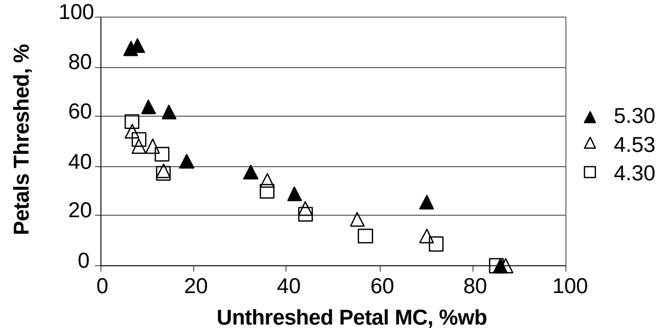

Figure 7. Percent of threshed petals vs. the unthreshed petal moisture content for the open dryer at 1X flower compaction and three airflows (volume changes/min).

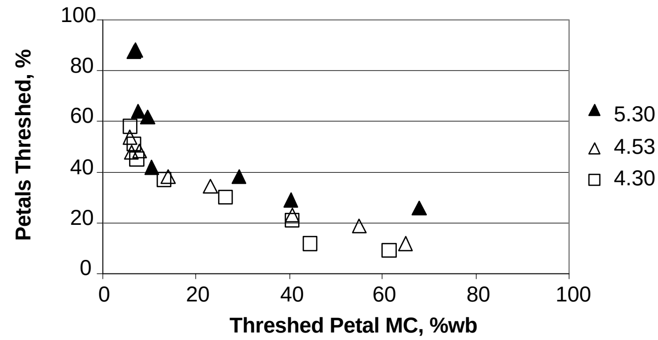

Figure 8. Percent of threshed petals vs. the threshed petal moisture content for the open dryer at 1X flower compaction and three airflows (volume changes/min).

1.5X compaction were similar while at 2X compaction there were 50% fewer petals threshed at petal moisture contents above 20%.

Conclusions

Both the sectored and open chamber dryers performed well in simultaneously drying and threshing petals from flowers. For most test operating parameters, more than 80% of the petals were threshed after 20 to 24 h of drying. Different levels of the operating parameters produced only minor differences in results. Threshing characteristics were different between the sectored and open dryer. The former had a relatively large increase in the threshing rate after about 10 to 15 h of drying while the open drying threshing rates remained fairly constant during drying. The open dryer produced more threshed wet petals that required additional drying. To reduce the threshing of high moisture petals, the open dryer could be rotated at lower speeds (or possibly not at all) during the initial 8 to 10 h of drying when moisture was still high. Threshed material from both dryers contained an insignificant amount of trash, i.e., fine, non–petal material. The threshing characteristics for both dryer types was practically unaffected by changes in operating speed, airflow, and compaction. However, comparing the 1X and 2X compaction levels, the capacity of the open dryer would be twice with greater compaction for the same rotational speed.

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