Marigold Petal Removal with a Plate Thresher

B. D. Britton, P. R. Armstrong, G. H. Brusewitz, M. L. Stone

Abstract. ***Abstract.*** *The petals of marigold flowers* (Tagetes erecta) *are commonly used as a feed supplement by the poultry industry to enhance broiler skin and yolk coloration. This research examined the effectiveness of a threshing device for removing petals from* Orange Lady *marigold flowers by scrubbing dried flowers between two moving plates. Thresher–associated independent variables were plate speed and distance between plates (plate gap). Flower moisture content was the independent variable representing flower properties. Efficacy was determined by measuring the threshing efficiencies and the percent trash (MOP, material other than petals) present in the threshed material. Results show smaller plate gaps had higher threshing efficiencies and increased MOP in the harvested samples. Threshing efficiencies ranged from 34% to 98% for high and low flower moisture contents respectively. Plate speeds ranging from 156 to 936 mm/sec had no effect on threshing efficiency.*

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

Marigold petals contain a high concentration of the yellow pigment xanthophyll relative to other plant materials and are the primary source of xanthophyll used in poultry feed. Dried ground petals are typically fed directly to chickens. Alternately, xanthophyll concentrate is extracted from the flowers and used as a liquid additive to the feed. Research by Scott et al. (1967) showed that poultry diets containing xanthophyll produced broiler skin and egg yolks with an intense yellow color that is desired by consumers. Research has been directed toward understanding how xanthophyll is metabolized by poultry and factors which influence its effectiveness (Fletcher et al., 1978, 1986; Janky et al., 1985; Papa et al., 1985; Hencken, 1992; Allen, 1993; Piccaglia et al., 1998).

Marigold flowers are grown in relatively large quantities (several thousand hectares) for xanthophyll production. Labor–intensive hand–harvesting of flowers confines production to countries with low labor costs. Steps used in marigold production include hand–harvesting, ensiling, drying, and pelletizing the material into an extractable form (Verghese, 1997). Raw pellets contain unwanted green material from the receptacles, stems, and leaves. A preferred harvest method would remove only petal material to produce a more concentrated product and reduce drying and extraction costs.

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The Biosystems and Agricultural Engineering and Horticulture and Landscape Architecture Departments at Oklahoma State University are investigating several aspects of mechanized production of marigold flowers. This research includes mechanical harvesting of marigold flowers, drying, removal of dried petals, and processing the petals into a product suitable for direct feeding or extraction. Buser (1997) studied thin–layer drying of marigold flowers to determine moisture diffusion rates. Petal components were found to dry faster than the receptacles. The differential drying rates were used to describe optimal moisture conditions for petal detachment by hand. Xanthophyll content of the petals was determined to be degraded by oxidation at higher dryer air temperatures.

The removal or threshing of petals from the receptacle could, potentially, be achieved using threshing concepts similar to those used for other crops (Price, 1993; Mesquita and Hanna, 1993, 1996). Problems unique to marigolds are the physical similarities between petal components and MOP (material other than petals, i.e., receptacle sheath and seeds). These similarities make post–threshing separation difficult. However, the different drying rates of these components could be used to minimize trash during threshing, because the receptacle remains more moist and less brittle.

A plate thresher built by Britton (1999) uses two orthogonally–moving, parallel scrubbing surfaces or plates to remove dried petals from flowers. Flowers situated between the plates are subjected to considerable rolling and scrubbing actions which break the brittle petals from the receptacle. The basic design of the machine showed promise in separating petals, depending on various settings. Operating factors expected to affect threshing were the distance between the plates or plate gap, plate speeds, and petal moisture contents. Small plate gaps or high plate speeds could cause excessive abrasion, resulting in receptacle breakage and MOP in the petals. However, large gaps or low plate speeds may not provide enough scrubbing action to remove petals. Petals need to be dried to moisture levels at which they become brittle, while over–drying may result in undesirable receptacle breakage.

The objective of this research was to determine the effect of thresher operating parameters and flower moisture on petal removal efficiencies.

Materials and Methods

Experimental Thresher

The main components that performed threshing were an oscillating top plate and an endless belt conveyor (Figure 1). The conveyor surface, which effectively forms the bottom plate, moves continuously in a direction perpendicular to the motion of the top plate. The top plate surface oscillates in a plane parallel to the conveyor surface and its motion is perpendicular to the conveyor motion. The thresher was designed to accommodate different plate speeds and gap widths (distance between the parallel scrubbing surfaces). Plate speeds affect the amount of threshing contact time that the flowers are subjected to. Plate gap affects the degree of scrubbing action between the plate and the belt.

The conveyor, which forms the bottom scrubbing surface, is 0.84 m wide by 1.4 m long. Support rollers (127 mm diameter) carry the belt. The drive roller is powered by a variable–speed DC motor through a gear reduction drive and a chain drive. Conveyor belting material is 120# tan 2–ply SBR Diamond Top (IBT, Merriam, Kans.). The belting has a laminated, three–dimensional diamond pattern on its surface. The diamond pattern is formed into the belt to a depth of 3.8 mm. The laminate is made of a soft elastic polyurethane foam that easily deforms and reforms when pressed. Elasticity of the laminate was expected to aid in the threshing process by allowing it to deform around larger flower receptacles and not crush them. A section of this belting material was also bonded to the entire underside of the top plate.

The reciprocating action of the top plate was achieved using a crank wheel and arm assembly driven by a variable–speed electric motor. A guide mechanism for the top plate was constructed from steel angle and acts as a rail system, using a combination of roller bearings and bronze sliding guides to restrict the movement of the plate to a linear motion. The effective stroke travel of the top plate was 180 mm. The plate dimensions were 862 mm long and 508 mm wide. The plate and rail system was adjustable to create different gaps between the plate and conveyor. Britton (1999) provides design details.

Conveyor speed was defined as the linear velocity of the belt (mm/s) and was adjusted using the variable–speed drive motor. The plate speed was adjusted with a variable–speed drive motor so that the stroke travel, divided by one–half the cycle period, was a either a factor of one or one–half the conveyor speed. The RMS plate speed was then determined from the velocity function of plate and used as the reported speed value (Figure 2).

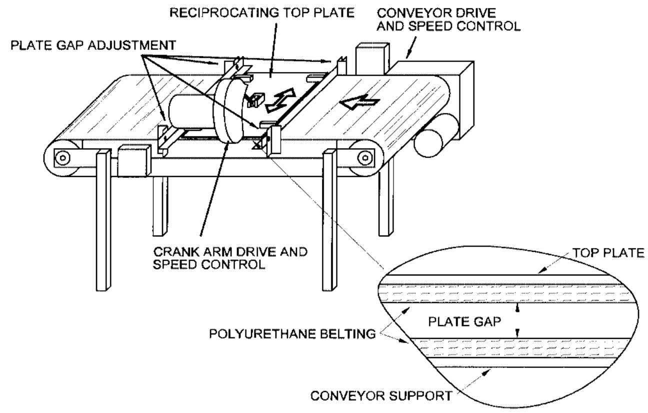


Figure 1. Schematic of the plate thresher.

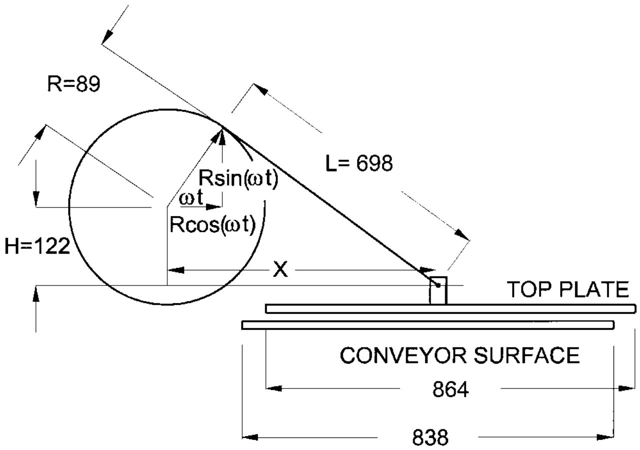
Marigold Flowers

Orange Lady marigold (*Tagates erecta*) transplants, used to supply test flowers, were planted in mid–May at the Oklahoma Botanical Garden and Nursery complex located in Stillwater, Okla. Flowers were hand–harvested, beginning in late June, at approximately 2–wk intervals. Flowers that were less than fully developed were left until the next harvest, while the past–mature flowers were picked and discarded. Flowers were placed in polyethylene bags and stored at 5° C until testing. Prior to threshing tests, flowers were dried in a single layer using a forced–air deep–bed dryer. Dryer air temperature was set at 66° C with an airflow of 0.3 m^3/s per m^2 of bed area. The bed area was sufficient to dry a single layer batch of about 1000 flowers.

General Test and Threshing Procedures

Samples of the flowers taken from each dryer batch were used to determine component moisture contents. Thirty flowers from a batch were hand–separated into petal and receptacle components. The components were then weighed and oven–dried at 103° C for 24 hours to obtain component moisture contents (wet basis) for individual and combined flowers. Average petal moisture content from these flowers was used as the basis for comparing threshing results.

Threshing was performed by placing each dried flower onto the moving conveyor, which forced them between the conveyor and threshing plate. Threshed petals and the receptacles (both with and without petals) were collected at the end of the conveyor and hand separated. The petals not removed by threshing were removed by cutting them from the receptacle with scissors. Threshed and unthreshed petals and receptacles were weighed and oven–dried to obtain moisture contents and to compute threshing efficiency (percent of petals threshed). MOP was carefully separated by hand from the threshed petal particles. MOP was oven–dried 24 h and weighed to obtain dry mass. Equations 1 and 2 were used to determine the percent of petals threshed and the percent trash based on the oven–dried mass of each component.



$$X = R\cos(\omega t) + \sqrt{L^2 - (H + R\sin(\omega t))^2}$$

Figure 2. Geometry of the plate thresher crank–arm. Equations of motion for displacement and velocity are given. Dimensions are in mm.

$$Threshing\ Efficiency = \frac{Threshed\ Petal\ Mass}{Threshed\ Petal\ Mass + Unthreshed\ Petal\ Mass} \times 100\% \qquad (1)$$

$$\%\ MOP = \frac{MOP\ Mass}{Threshed\ Petal\ Mass + MOP\ Mass} \times 100\% \qquad (2)$$

Experimental Design

The first experiment examined six combinations of plate and conveyor speeds, three plate gaps, and three flower moisture contents (Table 1). Flower moisture contents were paired with one of the three plate gaps. A sample of 20 to 25 flowers was used for each of the three replicates. Results from analysis of variance for different plate and conveyor speeds at a fixed plate gap and moisture content indicated threshing efficiencies were not significantly different. As a result, speed combinations were dropped as a treatment in order to focus on plate gap and flower moisture content.

The second experiment used all combinations of three plate gap settings (wide = 12.9 mm, medium = 9.7 mm , narrow = 6.5 mm) and three nominal petal moisture contents for four harvests. For each combination, three replications were performed using 30 flowers per replication. The conveyor and plate speeds were set at 560 and 626 mm/s for all tests. Flowers were dried to different moisture contents using drying time as the determining factor. Drying times were 12, 14, and 16 h. The actual moisture contents achieved for the same drying time varied considerably for different drying batches. The petal moisture contents for various drying times ranged from 7.0% to 14.1% for 12 hr, 10.2% to 17.2% for 14 h drying, and 18.0% to 30.9% for 16 h drying. This variation is attributed to different ambient air conditions during drying and inconsistent flower size. Data were analyzed using standard analysis of variance.

Results

Conveyor/Plate Velocity Experiment

Results from the first experiment indicated that conveyor and plate speed did not affect the threshing efficiency. Analysis of variance showed threshing efficiencies were not significantly different ($P < 0.05$) among speed combinations for a fixed plate gap and moisture content (Table 2, Figure 3). All of these speeds created an adequate threshing contact time for the flower conditions.

Table 1. Treatment levels for the first experiment.

Conveyor/Plate RMS Speed Combinations (mm/sec)	Petal Moisture Contents (% wb) and Associated Plate Gap (mm)
280 / 156	[9.6, 12.9], [9.1, 9.7], [7.8, 6.5]
280 / 313	[9.6, 12.9], [9.1, 9.7], [7.8, 6.5]
560 / 313	[9.6, 12.9], [9.1, 9.7], [7.8, 6.5]
560 / 626	[9.6, 12.9], [9.1, 9.7], [7.8, 6.5]

840 / 468	[9.6, 12.9], [9.1, 9.7], [7.8, 6.5]
840 / 936	[9.6, 12.9], [9.1, 9.7], [7.8, 6.5]

Table 2. Analysis of variance of conveyor/plate speed treatments on threshing efficiency for the three plate gap and moisture content combinations.

ANOVA Tables						
Source of Variation	SS	df	MS	F	P–Value	F crit
9.6% MC, 12.9 mm gap						
Treatments	278.3	5	55.7	0.442	0.811	3.106
Error	1511.8	12	126.0			
9.1% MC, 9.7 mm gap						
Treatments	33.3	5	6.7	0.169	0.969	3.106
Error	472.2	12	39.3			
7.8% MC, 6.5 mm gap						
Treatments	66.0	5	13.2	0.443	0.811	3.106
Error	357.8	12	29.8			

PLATE GAP/ MOISTURE CONTENT EXPERIMENT

Results of the second experiment using differing plate gap/moisture content combinations are shown in Figure 4. At moisture contents below 10%, the threshing efficiency was over 80%. Petal moisture contents greater than 30% resulted in threshing efficiencies less than 55%. Regression analysis indicated that the narrower plate gaps were slightly more effective in petal removal. Higher threshing efficiency was produced by more aggressive scrubbing action as the flowers are forced through a smaller space. While threshing efficiencies ranged from 35% to 98%, standard deviations across replicates ranged from 0.3% to 16.5%.

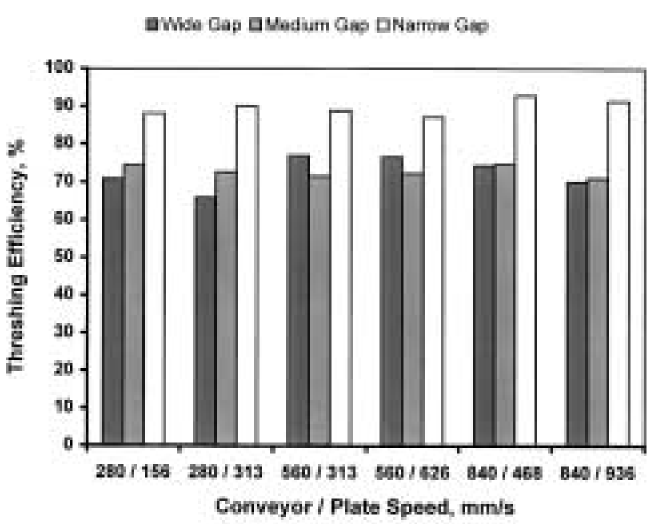


Figure 3. Threshing efficiency for different conveyor/plate velocity combinations and gap widths for the first experiment.

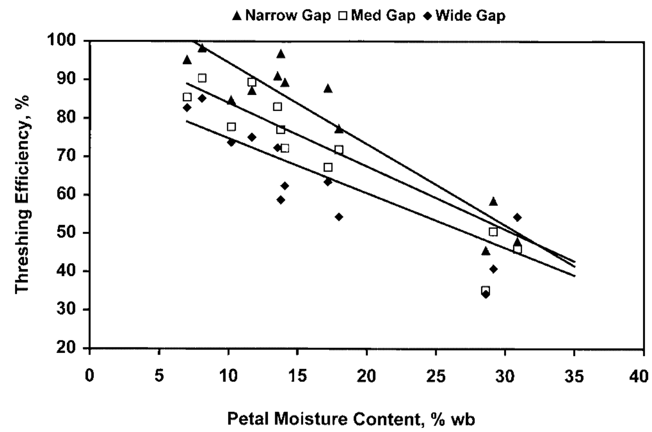


Figure 4. Threshing efficiency for different gap widths and flower moisture contents for second experiment. Each point is the mean of three replications.

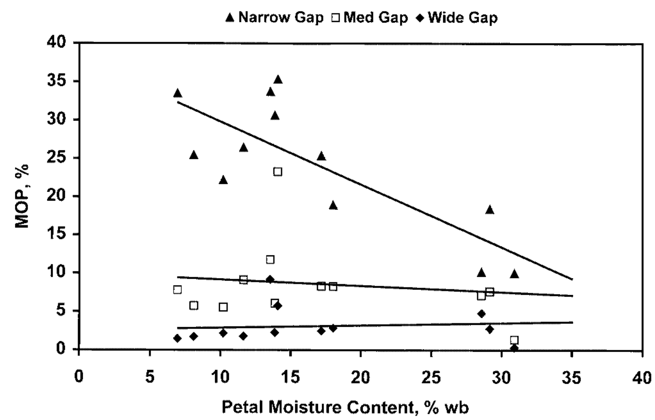


Figure 5. Percent of MOP (material other than petals) in the threshed petals for different gap widths and flower moisture contents. Each point is the mean of three replications.

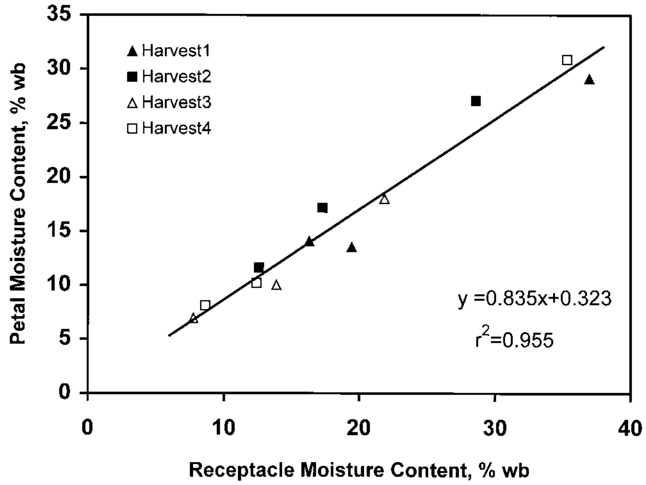


Figure 6. Petal versus receptacle moisture contents of dried flowers. Each point is the mean of components from 30 flowers.

The compromise between achieving a high percentage of petal removal and minimizing MOP material in the threshed petals is illustrated in Figure 5. The percent of MOP in the threshed petals increased considerably for the narrow plate gap at low petal moisture contents, but remained nearly constant for the medium and wide plate gaps. The narrow plate gap most likely caused excessive abrasion of the receptacle resulting in trash in with the petals.

Moisture contents of the petal and receptacle components used for threshing tests show that the receptacle dried more slowly than the petals. The relationship between the petal and receptacle moisture content is shown in Figure 6. The regression indicated that the petal moisture content was, on the average, 83.5% of the receptacle moisture content.

The average moisture content of the threshed portion of petals over all harvests was 6.9 % (SD = 0.51%). This moisture content includes MOP because it was impossible to separate this component in a timely manner to avoid hygroscopic adsorption of atmospheric moisture. This indicates that regardless of the average total petal moisture content (which ranged from approximately 6% to 31%), or gap width settings, only the petal portion that was near 7% moisture content was threshed. It was observed that, after drying, outer petal parts were drier than the inner petal and consequently were threshed more readily.

Flower component mass generally decreased with harvest date (Figure 7). Adjustment of plate gaps based on seasonal harvest changes in flower or receptacle size may be desirable to obtain maximum threshing efficiency with minimum trash content.

Conclusions

As petals were dried to less than 10% moisture contents, at least 80% of all the petal mass was removed by the plate thresher for all plate gaps. Narrower plate gaps removed more petals at higher moisture contents, but also increased the trash content in the samples. Petals at higher moisture contents produced less threshed material than from drier petals. The amount of trash in the threshed petals increased considerably for narrow plate gaps and lower petal moisture contents. For medium and wide plate gaps it was nearly constant for all petal moisture conditions. Over the range tested, velocities of the top plate and conveyor surface did not affect the percent of petals threshed.

Petal moisture contents were approximately 85% of receptacle moisture contents after 12 to 16 h drying. Outer petal parts dried more quickly than inner petal parts, and unthreshed petal material always had higher–moisture inner petals. Petal moisture contents that are conducive to threshing are near 7% (wet basis) or less. Flower component mass (petals and receptacles) decreased with subsequent harvests.

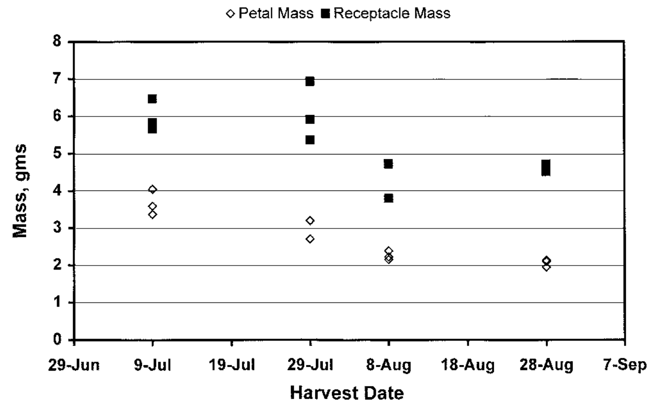


Figure 7. Flower component mass by harvest date. Each point is the mean of components from 30 fresh flowers.

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