The Role of Maturation in Quality of Stackpole-Cured Peanuts[1]

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ABSTRACT

Peanut curing studies utilizing stackpole curing led to the unique observation that extensive potential for post harvest maturation exists during slow curing. In the hull scrape maturity profile the percentage of black maturity class pods increased from 15 to 45% and 21 to 57% in *ca.* 30 d after stacks were prepared in 2 consecutive years. Simultaneously, the number of pods in less mature classes generally decreased. The weight percentage of black pods increased from 19 to 42% and 37 to 62% after 10 stack d in the 2 yr. A similar but less extensive maturity progression was observed in detached pods in a temperature-relative humidity-controlled environment where drying rate was faster than in stackpoles but much slower than in conventional practices. Because pod and seed sizes did not change during stackpole curing, maturation resulted in large increases in the percentage of mature peanuts (maturity distribution) in all commercial grade sizes. Moisture contents for orange and brown maturity classes related to cessation of color change in pods in both stackpoles and controlled environment treatments were about 29.0 and 22.5%, respectively. Occurrence of physiological seed maturation concurrently with hull color progressions was verified by the consistent oleic acid/linoleic acid ratio in medium grade-size peanuts within each maturity class over curing time.

Key Words: Hull scrape, maturity, moisture content, maturity profile, curing, O/L ratio.

The unique flavor of roasted peanuts is the underlying basis for consumer purchase and consumption of peanuts (*Arachis hypogaea* L.). An understanding of the physiological and biochemical factors responsible for consistent full flavor development is critical to enhancing methods presently used to obtain the high flavor quality of U.S. peanuts and to develop more efficient technology for production of maximum roast flavor. Although studies on various biochemical changes relative to maturity and curing have been conducted (5, 7, 8, 9, 11, 13, 15, 17), a comprehensive study to examine a wide range of biochemical, volatile, and descriptive flavor factors has not been reported. To obtain such data, an experiment was planned to slow down the peanut curing process to sequentially examine the physiological and biochemical processes taking place in various maturity stages. Stackpole curing and a temperature-relative humidity- (RH) controlled environment were the methods of choice to obtain slow curing. The stackpole was included because discussions continue to extol the quality merits of stackpole curing over those of present day practices. Bulk curing with heated air is today the method of choice because of the significant benefits in time and labor.

The information reported herein was a unique observation in a study originally designed to provide peanuts for basic biochemical studies (14). These observations may explain the long-standing perception that stackpole curing results in very high quality peanuts. The findings relate to peanut maturation, based on hull scrape color progressions, that occurred during long-term curing regardless of whether or not pods were attached to plants. This phenomenon with regard to stackpole curing was suggested by Lambert (4) and Norden (6). However, those reports only suggested the possibility of continued peanut maturation while pods were still attached to the plants. We report the unique phenomenon of apparent peanut maturation of attached and detached pods during slow curing and oleic acid/linoleic acid ratio as verification of physiological seed maturation (14) in concert with the obvious pod color changes that occurred during stackpole curing.

Materials and Methods

On 27 April 1989 and 1990, Florunner peanuts were planted at the National Peanut Research Laboratory, Dawson, GA. Conventional cultural practices were used and irrigation was applied as needed based on Delmhorst gypsum blocks located in 10 locations at 5 and 31 cm below the soil surface.

On 26 Aug. 1989 [121 d after planting (DAP)], approximately 465 m of row length of peanuts were dug and pods were hand-picked, washed, and riffle-divided into nine equal samples of *ca.* 27 kg (fresh weight). One sample, processed as the initial sample (Day 0), was separated into hull-scrape maturity classes based on the nondestructive maturity method of Williams and Drexler (14). Half of the orange and brown maturity classes were hand-shelled, flash-frozen with liquid nitrogen, and stored at -20 C for later analysis. The remainder of the orange and brown and all of the yellow 2 and black maturity classes (minus two *ca.* 50-g samples of each class for moisture determinations) were cured in mesh bags on a forced-air drier at ambient, but not less than *ca.* 27 C, to 6-7% moisture. Cured peanuts were subsequently hand-shelled and separated into four commercial grade sizes using 8.33, 7.14, 6.35, and 5.56-mm width slotted screens as previously described (10) and stored at -15 C until analyzed.

The remaining eight samples of freshly harvested peanuts were put into mesh bags and randomly placed on wire-mesh

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shelves in a 12.8 m^3 insulated chamber in which RH and temperature were controlled with a 1000 CFM self-contained temperature/relative humidity conditioner (Parameter Generation and Control, Inc.). Initial temperature and RH were adjusted to 26.7 C and 90%, respectively. Temperature was held constant for the curing period, while RH was progressively lowered to 70% over a 13-d curing period. Copper-constantan thermocouples and PCRC-11 relative humidity probes (Phys-Chem. Scientific Research Corp.) were used to monitor temperature and RH, respectively, during the curing period. Data were recorded at hourly intervals on magnetic tape using a Monitor Labs, Inc., Model 9302 datalogger interfaced with a Phys-Chem. Scientific Research Corporation signal conditioner and a Techtran tape recorder. Samples were removed after 1-5, 8, 10, and 13 d in the chamber and processed the same as the initial sample.

On 28 Aug. 1989 (123 DAP), four conventional peanut stacks were made using freshly hand-harvested peanuts from the same field as those placed in the RH-temperature chamber. On 6 Sept. 1990 (132 DAP), four stacks were made but the controlled temperature/RH study was not repeated. Poles for the stacks were 2.15 m tall and the crosspieces on the bottom of the pole were 30.5 cm above the soil. Stacks were made by stacking plants with peanuts generally oriented inward, toward the pole, until the pole was completely covered. Temperature and RH were recorded using copper-constantan thermocouples and Model 207 temperature and relative humidity probes (PCRC-11 relative humidity sensor and a Fenwal Electronic UUT51J1 thermistor configured for use with a CR7 datalogger (Campbell Scientific, Inc., Logan, UT). Sensors placed in all stacks near the center of the stack, 45.7 cm above the bottom of the stack, and 45.7 cm below the top of the stack were connected to a CR7 datalogger scanning on an hourly schedule. Sensors to measure ambient conditions were placed in the shade *ca.* 1.5 m above the soil. The section of the stack between the top and bottom sensors was used as the total sample in all subsequent tests. In 1989, individual stacks were harvested on 7, 18, 28 Sept., and 10 Oct. [days after stacking (DAS) of 10, 21, 31, and 43, respectively]; and in 1990 stacks were harvested on 17, 27 Sept. and 7, 17 Oct. (DAS of 11, 21, 33, and 42, respectively). At harvest, peanuts from the stacks were processed into hull scrape maturity classes, weight of peanuts in each maturity class was determined, and samples were taken for freezing and moisture as described earlier. Peanuts in each maturity class were subsequently cured to 7 to 8% moisture using forced air. In 1989, the initial sample (121 DAP) was utilized as the Day 0 sample in the stackpole data even though peanuts used in the stacks were actually harvested 2 d later (123 DAP). In 1990, the Day 0 sample was collected at the time of stacking. Peanuts were shelled and sized over slotted hole screens to determine grade size as previously described (10).

Hull scrape maturity profile (pod count) was determined on duplicate *ca.* 200 pod samples riffle-divided from pods harvested at each sample date. Percentage moisture was determined by placing hand-shelled seed from each maturity class in a forced-draft oven at 130 C for a minimum of 6 hr (2).

Fatty acid profiles of medium grade-size peanuts from each maturity class were determined on oil extracted from *ca.* 20 g of ground peanuts with 100 mL of petroleum ether. Methyl esters of the whole oil were prepared as reported earlier (9) and injected in chloroform into a Hewlett-Packard 5890 gas chromatograph fitted with a flame ionization detector. The 3.18 mm × 1.83-m stainless steel column was packed with 5% DEGS-PS on 100/120 mesh Supelcoport (Supelco, Inc., Bellefonte, PA). The carrier gas was helium at 30 mL/min and the column was operated isothermally at 200 C. Injector and detector temperatures were 225 and 250 C, respectively. Fatty acids were identified with appropriate standards and percentages were determined with a Hewlett-Packard 3396 A Integrator.

Results and Discussion

Initial temperature and RH in the controlled environment used to slow cure peanuts (Fig. 1) were based on approximate stackpole curing conditions reported by Cole *et al.* (3). Moisture content was determined at each sampling of peanuts from the controlled environment (Fig. 2) and these values were used to estimate needed reductions in RH to lower peanut moisture content to approximately 11% over the 13-d period. Reductions in RH were required to achieve continual moisture reduction in the peanuts.

Temperatures in the stackpoles generally followed ambient temperature (Fig. 3). RHs in stacks were gen-

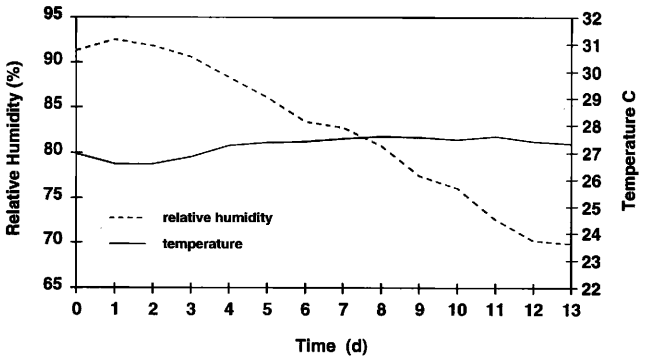

Fig. 1. Relative humidity and temperature conditions in a controlled environment used for slow curing of peanuts.

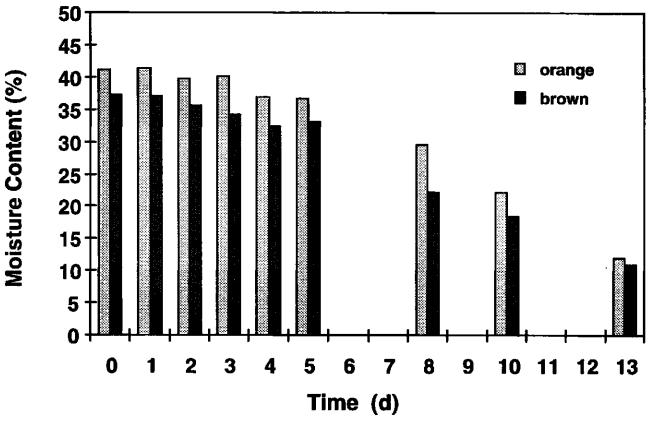

Fig. 2. Seed moisture content of orange and brown maturity class peanuts slow cured in a controlled environment.

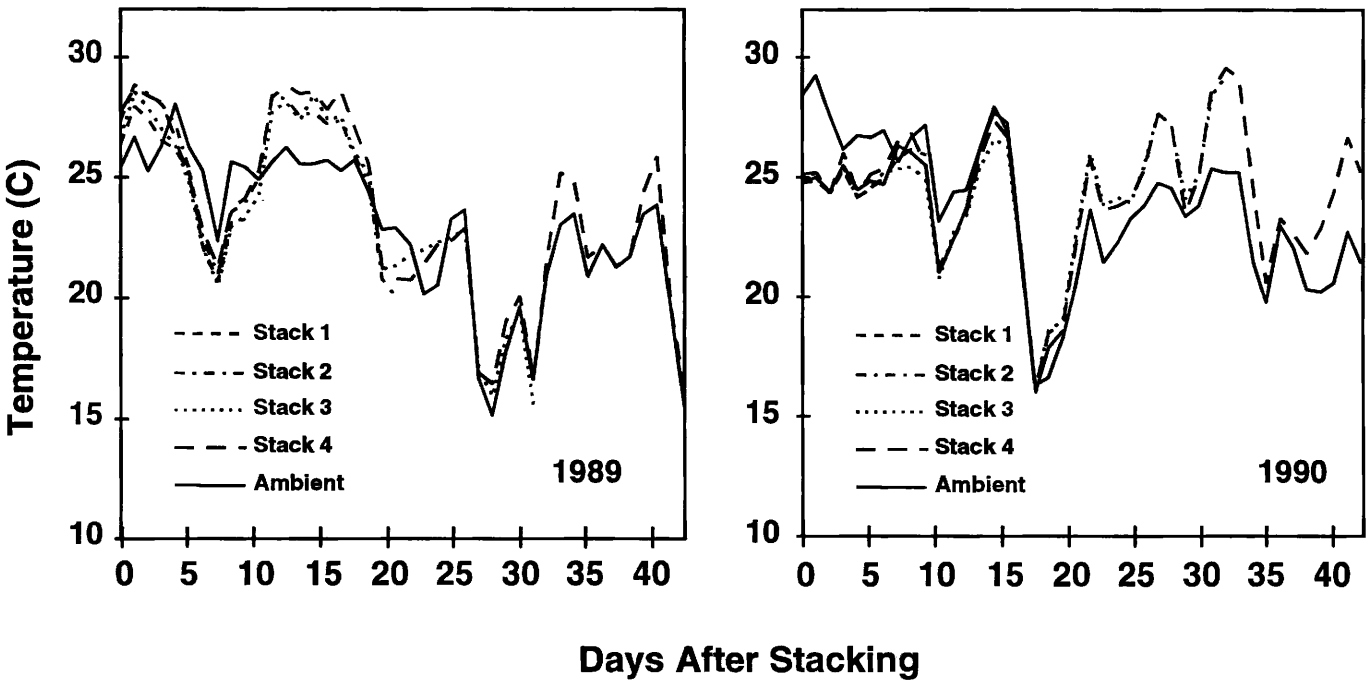

Fig. 3. Temperature inside four peanut stacks which were harvested at *ca.* 10-d intervals.

erally slightly higher than ambient and remained higher until 20 DAS (Fig. 4) in both years. A low of 70% RH was required to achieve average moisture of about 10% for all maturity classes in 13 d in the controlled environment (Fig. 2). Slightly higher moistures ranging from 10 to 15% (Fig. 5) were found in the stack peanuts after 43 DAS in 1989 and 42 DAS in 1990. RH was generally higher than 75% (mean of 81.6) in 1989 and lower than 70% (mean of 63.0) in 1990 throughout most of the treatment period.

Peanut maturation during stackpole curing is evident because the percentage of black pods increased from 15 to 45% in 1989 and from 21 to 57% in 1990 (Fig. 6). The reduction in number of pods in yellow 2, orange, and brown classes and the increase in number of black pods indicate that pod color changes of considerable magnitude occurred between 0 and *ca.* 21 DAS. Data for 10 and 43 DAS based on pod count were not recorded in

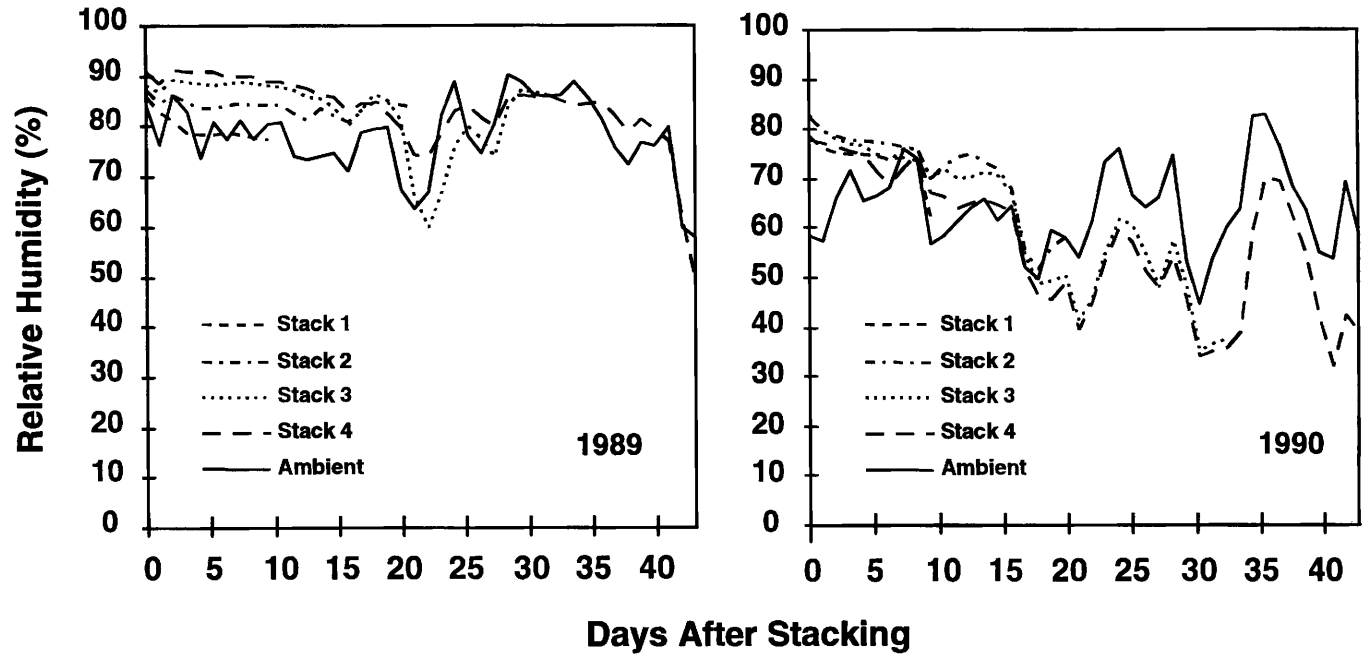

Fig. 4. Relative humidity inside four peanut stacks which were harvested at *ca.* 10-d intervals.

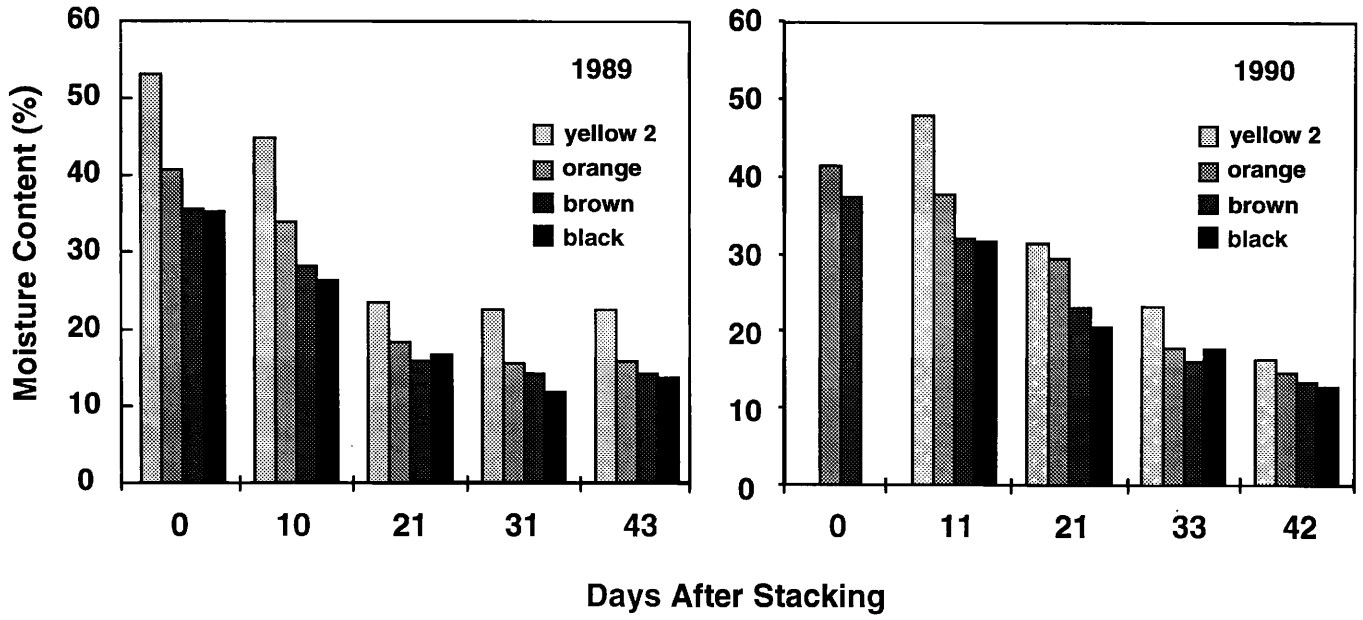

Fig. 5. Seed moisture content of peanut maturity classes from stackpoles harvested at *ca.* 10-d intervals.

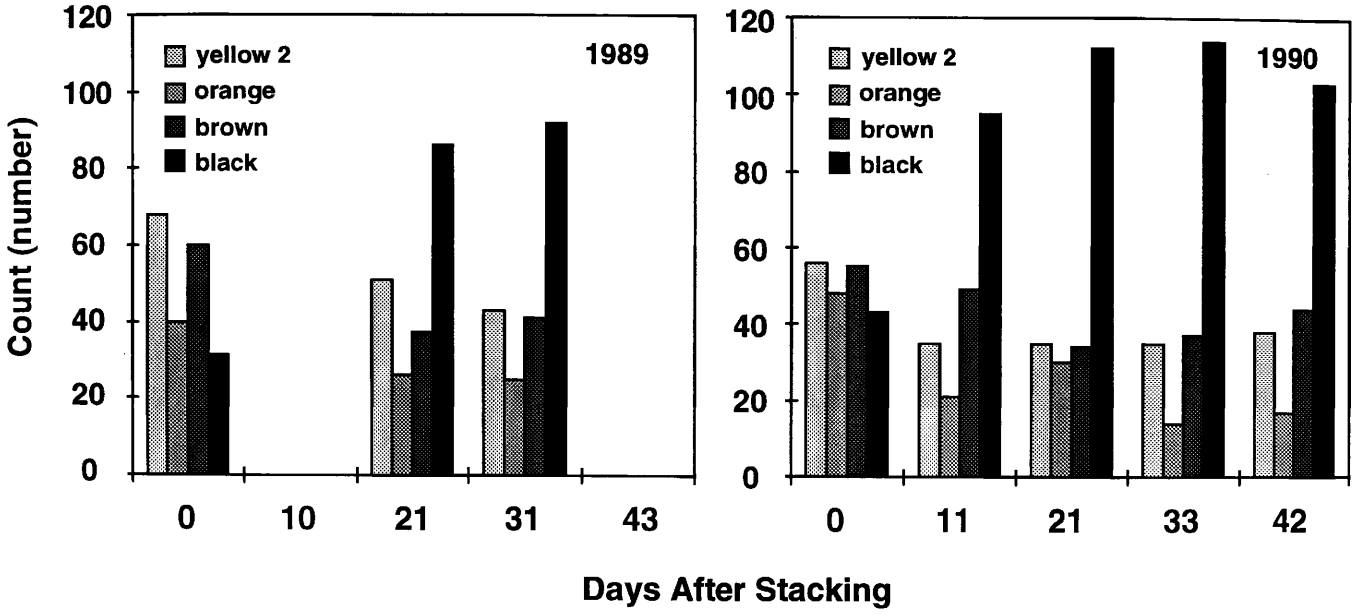

Fig. 6. Pod maturity profile of peanuts from stackpoles harvested at *ca.* 10-d intervals.

1989. Progressions into and out of the yellow 2, orange, and brown classes were not quantitatively observable in a pod count analysis. However, reduction in number of pods in the three classes dictates that turnover occurred (Fig. 6). The maturity progression in peanuts curing in stackpoles was typical of changes observed in normal growth (16) wherein the number of black and brown pods on plants generally increase as optimum harvest date approaches. Date of harvest (121 DAP in 1989, and 132 DAP in 1990) appeared to have little relation to the maturation potential in stacks. In a separate study conducted at a commercial farming operation, peanuts stacked at 143 DAP (optimum hull scrape harvest date), the percentage of black pods increased from 36 to 70% in 30 d while all other maturity class percentages decreased (data not presented). Sanders and Pearson (12) demonstrated continuation of physiological processes after harvest by the large increase in percentage of purple testa peanuts produced when windrowed peanuts were misted for 10 d.

The change in pod weight percentage of various maturity classes in progressive stacks (Fig. 7) and in the controlled environment (Fig. 8) provided further evidence of peanut maturation during slow curing. Pod

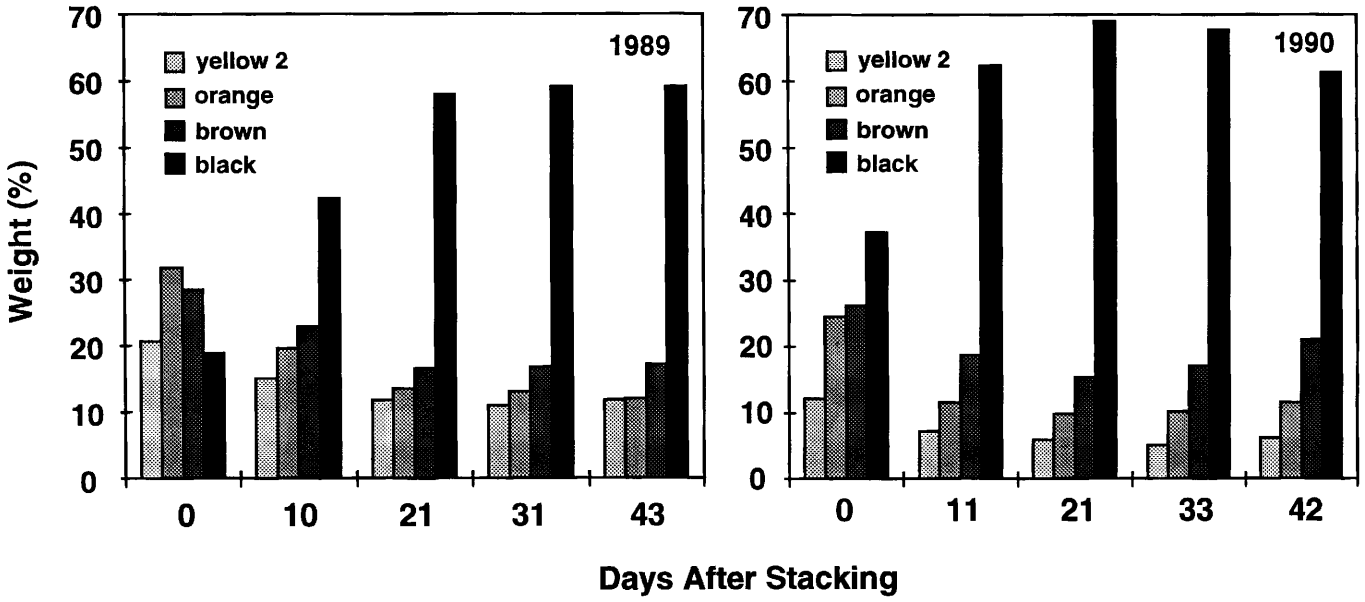

Fig. 7. Maturity class pod weight percentages from stackpoles harvested at *ca.* 10-d intervals.

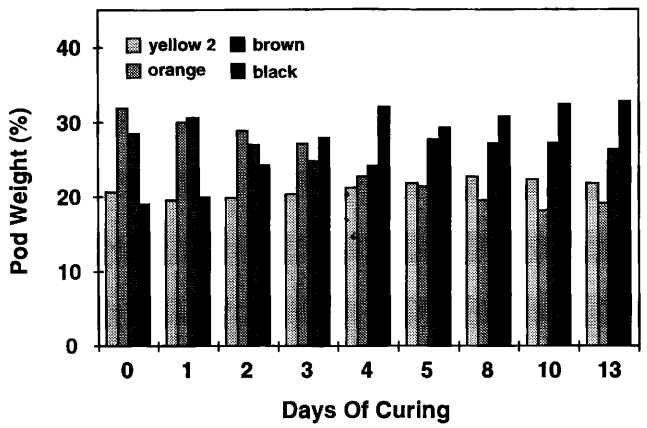

Fig. 8. Maturity class pod weight percentages from peanuts slow cured for 13 d.

weight percentages are based on the total weight of pods harvested from stacks. These data examined singly could be interpreted as simply an increase in weight of individual pods in a maturity class and not an increase in the number of pods in each class; however, the pod count data in Fig. 6 preclude any such incorrect conclusion. In both years after 10 DAS, percentages for all maturity classes decreased (smallest decrease occurred in the brown class), except in black which increased from 19 to 42% (1989) and 37 to 62% (1990) (Fig. 7). Similar changes continued at 21 DAS when percentage weight of black pods had increased to 58 and 69% in 1989 and 1990, respectively. Maturation changes were not as large in the controlled environment as in the stackpole peanuts; however, data indicate that after only 1 d, the percentage of orange pods had decreased and percentage of brown and black pods had increased. Thereafter, consistent progressive changes resulted in an increase from 19.0 to 32.7% of black pods and a final percentage of *ca.* 27% of brown pods. Some continued change in percentage of brown pods occurred after the black pod percentage had reached a maximum. On Day 8, the maturity profile percentages appeared to have stabilized and did not change through Day 13. Because pods were detached from plants in the controlled environment, plant attachment is not essential for pod color changes. The degree of maturation may be related to attachment; however, the rate of moisture removal is probably more critical to the difference in maturity progression between the two treatments.

Changes in maturity profile were minimal after Day 8 in the controlled environment and after 21 DAS in both years. At these sample times, moisture content of orange and brown maturity classes from the two treatments were similar in 1989 (orange—29.5 and 29.4%; brown—22.2 and 23.0%, respectively; Figs. 2 and 5), but slightly lower in 1990 stacks. The significance of these similar moisture contents in relation to the physiology of maturation is presently unknown. The specific physiological process examined, hull color change, may be terminated near these moistures while other aspects of peanut physiology may be controlled at higher or lower moisture contents. Mohapatra and Pattee (5) found that during progressive dehydration a seed moisture range of 44 to 47% played a critical role in changing the dominance of lipid anabolism to lipid catabolism. Hull color changes in stackpole and in the controlled environment ceased to occur after moisture content declined to 22-29%, suggesting that a specific moisture content is critical to the regulation of pod color changes.

Peanut grade size distributions from the Day 0 sample and successive stacks were essentially the same (Fig. 9) indicating that the peanuts did not change in size during

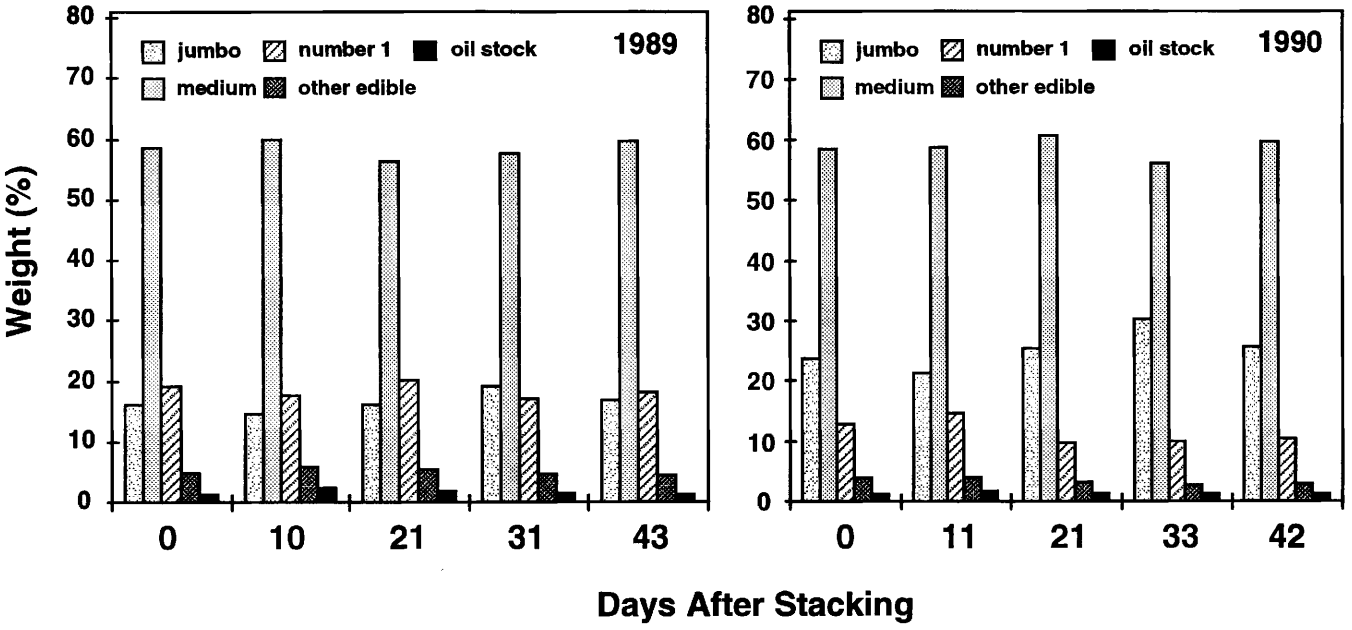

Fig. 9. Peanut grade size distributions from stackpoles harvested at *ca.* 10-d intervals.

the stackpole curing. This information, in conjunction with continuing maturation, indicates that the percentage of each maturity class within a grade size (maturity distribution) changed. Calculated maturity distributions in medium grade-size peanuts confirms that such a change occurred (Fig. 10). In the medium grade size, the percentage of peanuts from the black maturity class pods increased from 22 to 64% in 1989, and 38 to 70% in 1990 during Day 0 to 21 DAS, respectively. Sanders (10) reported that commercially sized cv. Florunner peanuts may contain widely varying maturity distributions and, because of the biochemical differences in maturity classes, the relative percentage of mature peanuts in a grade size lot thus impacts the quality (flavor, storability, etc.) of that lot. The large increase in the percentage of mature seed in the medium size due to maturation during stack curing should result in a higher quality lot of peanuts. Similar maturity distribution changes were observed for the jumbo and number 1 grade sizes (data not presented). The common assumption that stack-cured peanuts are of generally higher quality may in fact be due to the higher proportion of mature peanuts in each grade size.

Thus far, the term maturation has been used broadly to include the entire fruit when, in fact, the only measure of maturity was hull color. Published information indicates that oleic acid/linoleic acid (O/L) ratio in peanut oil increases with hull color changes until the late brown and black classes (11). Thus, if O/L ratio does not decrease in oil from seed in the brown or black maturity classes (or

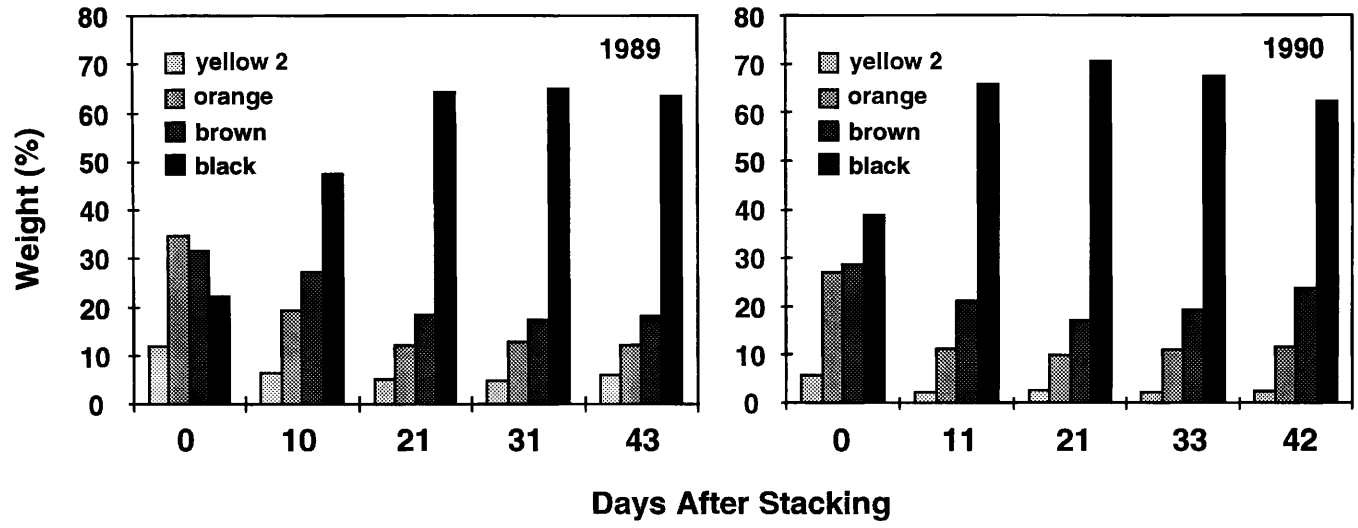

Fig. 10. Maturity distributions in medium grade-size peanuts from stackpoles harvested at *ca.* 10-d intervals.

any class) in progressive stacks, there is strong indication that immature seed were not being placed into those classes. Conversely, if immature seed are found in pods that changed to brown or black while in the stackpole, a decrease in O/L ratio should be observable in progressive stackpole samples of those classes. The O/L ratio was consistent within maturity classes from each stack (Fig. 11). Ratios within a maturity class varied only 0.05 to 0.07 from harvest to 43 DAS. These data indicate that seed physiological changes occurred along with hull color changes.

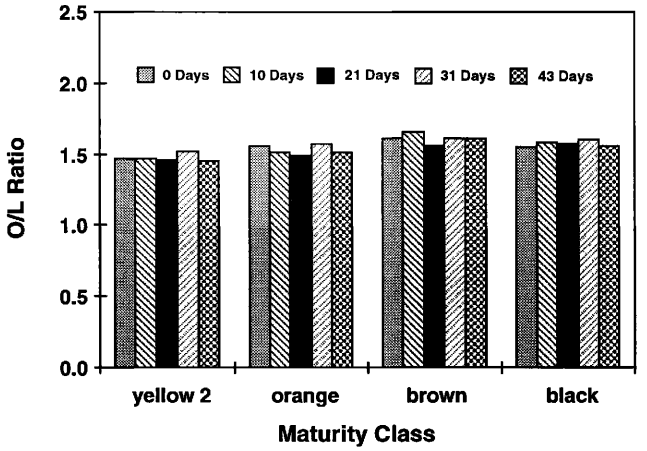

Fig. 11. Oleic/linoleic acid ratio in oil from maturity classes of stackpole-cured peanuts.

Vercellotti *et al.* (14) recently published an in-depth study of carbohydrate content and composition of peanuts from both of the crop years used in the work reported here. As in the case of O/L ratio, they reported that peanuts from black and brown pods from the Day 0 sample and peanuts from black and brown pods from all subsequent stack sampling dates were indistinguishable based on total carbohydrate or the concentration of individual sugars. Immature peanuts that merely appeared to be mature based on hull color would have skewed the biochemical characteristics of the brown and black classes toward a more immature character.

Summary

Peanut maturation, as measured by progressive hull color changes, occurred during stackpole and slow curing in a controlled environment. Maturation appeared to stop after moisture content declined to 20-30%. The maturity distribution in each commercial shelled grade size changed toward higher percentages of mature seed during stackpole curing. Shelled, sized lots from stackpole curing should, therefore, have improved flavor, storability, and general superior quality characteristics compared to peanuts that are rapidly cured. The data support the long-standing idea that stackpole-cured peanuts are of superior quality to peanuts bulk cured with heated air. Further, discovery of this maturation phenomenon provides a unique model system for study of the physiology of maturation which has potential for identification of processes, compounds, activators, etc. that might be manipulated by classical breeding or genetic engineering to enhance early or timed maturation in peanuts.

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