Effect of Peanut Blanching Protocols on Bed and Seed Temperatures, Seed Moisture, and Blanchability[1]

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ABSTRACT

Medium commercial size, runner-type peanuts were heated in an air flow direction-controlled lab scale oven to simulate an industrial multizone dryer used in peanut blanching. Nine blanching protocols consisting of three heating times (30, 45, and 60 min) factorially paired with three final oven set point temperatures (76.7, 87.8, and 98.9 C achieved from 32.2 C over six heating zones) were tested for effects on blanchability, moisture content, and temperature variation within individual seed and within the bed of peanuts. Temperature through the peanut bed varied as air flow (76.2 m/min) was reversed in alternating zones. Bed temperature variation during the heating process was highest in the 30-min protocols where the maximum difference between the top and bottom of the bed reached 17.6 C. Temperature variations decreased in the 45- and 60-min protocols; however, maximum differences as high as 8.1 C were consistently found. Bed temperature variation was related to air flow direction with higher temperatures in the peanuts nearest the air/heat source. Peanuts opposite the air flow direction did not reach the desired maximum temperature in the last zone of any protocol. Seed temperature variation was as much as 5 C between the seed surface and 3.14 mm into the seed. Seed moisture decreased from *ca.* 5.5% to a low of 2.94% in the 60 min/98.9 C protocol. Blanchability reached an upper limit of 71 to 75% in the 45- and 60-min protocols at 87.7 C and all of the protocols at 98.9 C. Blanchability was unrelated to magnitude of temperature variation in either seed or within the bed. Blanchability correlated positively with final oven set point temperature and negatively with final moisture content when moisture content was above 3.8%.

Key Words: Air flow, *Arachis hypogaea* L., production, quality factors.

Peanut blanching is an important step in the preparation of peanuts for further manufacturing processes. The most common process consists of drying the peanuts with heated air and then subjecting the peanuts to some method of removing the seed coat which has been loosened by the drying process. The blanching process results in seed coat removal and affects both post-blanching enzyme activity and moisture content, factors which may impact subsequent peanut quality. Information on industrial blanching protocols is proprietarily limited. However, common industrial methods are approximated by increasing heated air temperatures from *ca.* 32 to 88 C through several separate zones over *ca.* 45 min. Improper blanching conditions may lead to poor seed coat removal as well as problems with storage stability and flavor changes. Blanchability is thought to be influenced by initial moisture content, drying rate, thermal expansion, and moisture contraction (Paulsen and Brusewitz, 1976a,b; Farouk *et al.*, 1977). Temperature variation among individual peanuts of various size during the blanching process may result in variation in enzyme inactivation, moisture loss, blanchability, and storage stability (Pattee and Singleton, 1971; Paulsen and Brusewitz, 1976a; St. Angelo *et al.*, 1977). Variation in temperature during blanching may be related to peanut bed depth, location of individual seed in the bed, heat transfer into individual seed, and air flow (Adelsberg, 1995).

Although some reports on the effect of blanching on peanut quality have been published, none have addressed optimization of blanching conditions for peanut quality factors. Oven temperatures for blanching studies have generally been reported, but little information has been provided concerning the effect of heating time and temperature protocols on seed and bed temperatures, moisture content, blanchability, or other quality factors. This study was conducted to determine the effect of nine time-temperature blanching protocols on blanchability, moisture content, temperature variation within the bed of peanuts, and temperature variation within individual peanuts in the bed.

Materials and Methods

Peanut Source. Peanuts (*Arachis hypogaea* L., cv. Florunner) from the 1992 crop grown in Terrell County, GA were used in all tests. Peanuts were harvested at the optimum hull scrape harvest date, cured, shelled, sized, and stored at 4 C. Medium commercial grade peanuts (size range 7.1 to 8.3 mm width) were used for all tests.

Blanching Protocols. Total heating time and maximum oven set point temperature were both tested at three levels for a 3 × 3 factorial experiment (Table 1). In each of the nine protocols, heating began at 32 C and was increased stepwise through six heating zones to a final temperature of either 76.7, 87.8, or 98.9 C. Total heating times were 30, 45, or 60 min with the duration in each heating zone being 5, 7.5, and 10 min, respectively.

Blanching Methods. Industrial peanut blanching operations typically use conveyor belts to move peanuts slowly through large ovens. These ovens are divided into heating zones in which the direction of heated air flow alternates from top to bottom of the bed in successive zones (Fig. 1). The air temperature increases from one zone to the next. To

[1]The use of trade names in this publication does not imply endorsement by the U.S. Dept. of Agric. or the North Carolina Agric. Res. Serv. of the products named, nor criticism of similar ones not mentioned.

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Table 1. Dwell times and oven temperature settings for heating zones in blanching protocols.

Protocol	Time in each zone	Total heating time	Heating zone 1	2	3	4	5	6
	min	min	C					
1	5.0	30	32.2	41.1	50.0	58.9	67.8	76.7
2	7.5	45	32.2	41.1	50.0	58.9	67.8	76.7
3	10.0	60	32.2	41.1	50.0	58.9	67.8	76.7
4	5.0	30	32.2	43.3	54.4	65.6	76.7	87.8
5	7.5	45	32.2	43.3	54.4	65.6	76.7	87.8
6	10.0	60	32.2	43.3	54.4	65.6	76.7	87.8
7	5.0	30	32.2	45.5	58.9	72.2	85.6	98.9
8	7.5	45	32.2	45.5	58.9	72.2	85.6	98.9
9	10.0	60	32.2	45.5	58.9	72.2	85.6	98.9

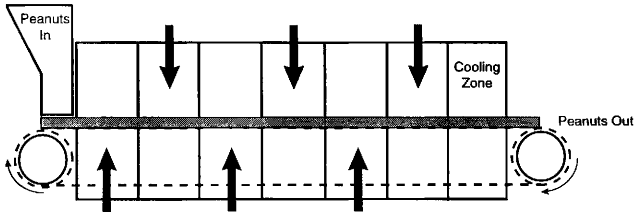

Fig. 1. Schematic of a six-zone oven used in commercial blanching of peanuts. Arrows indicate direction of air flow.

simulate and study this operation in a more compact and controllable environment, a Proctor and Schwartz single-chamber, flame-heated oven with airflow direction control was used to supply dry-heated air to peanuts placed in a basket within the oven. A steel mesh basket (22.9 × 40.6 cm) was filled with test peanuts to a depth of 12.7 cm. To avoid edge effects, this basket was placed within a larger basket containing filler peanuts to a depth of 12.7 cm (a depth typical of industrial operations). The larger basket was designed to fit snugly into the oven so that all flow occurred through and not around the test and filler peanuts. By alternating the air flow direction at timed intervals and increasing the oven set point temperature in successive intervals, the peanuts in the single chamber oven were exposed to temperature and air flow regimes similar to those along a conveyor belt in an industrial oven.

Peanuts were blanched according to the protocols outlined in Table 1. Air velocity was maintained at 76.2 m/min. Air flow direction was up in odd-numbered zones and down in even-numbered zones. Temperatures were increased in stepwise fashion at the time intervals shown in Table 1. The protocols were executed in order from 1 to 9 and then duplicated in the same order. After heating, the peanuts were immediately cooled with forced air at room temperature (*ca.* 23 C) for 4 to 5 min until bed temperatures were about 30 C. Samples of 300 g were immediately placed in tightly sealed glass jars for moisture content determination (AOAC, 1990). A small-scale blancher (Model EX, Ashton Food Machinery Co., Inc., Newark, NJ) with counter-rotating grit rollers was used to remove the seed coats loosened by the heating treatments. Peanuts were processed once through the blancher and then placed in cold storage.

Temperature Measurement. Five type T thermocouples were evenly distributed between 1.5 cm from the top and 1.5 cm from the bottom at the center and one corner of the inner basket to measure peanut bed temperatures during blanching. Hypodermic thermocouples (Omega, Inc., Stamford, CT) contained in 33-gauge, 2.54-cm long stainless steel hypodermic probes were used to measure internal seed temperature. To control the depth of insertion of each hypodermic thermocouple inside the seed, tape was placed on probes at premeasured lengths. Thermocouples were inserted into different peanuts at depths of 1.22, 1.60, 2.4, 2.84, 3.14, 3.34, and 3.50 mm. All peanuts containing hypodermic thermocouples were located at a depth halfway between the top and the bottom of the bed (6.4 cm). Peanut bed temperatures and internal seed temperatures were recorded at 20-sec intervals with a Campbell Scientific CR7 data logger interfaced with a computer with PC208 Datalogger Support Software (Campbell Scientific, Inc., Logan, UT).

Moisture. Samples of 50-g samples were heated in a vacuum oven for 48 hr at 70 C (AOAC, 1990), and moisture content was calculated as a percentage of dry weight.

Blanchability. A 250-g sample of peanuts from each protocol was visually inspected and sorted into blanched, partially blanched, and unblanched seed categories. In the calculation of percentage blanched, the partially blanched seed were classified as unblanched. Statistical analyses were accomplished using the General Linear Models Procedure (SAS, 1989).

Results and Discussion

Bed Temperature. Data collected in this study demonstrated that considerable temperature variation existed within the peanut bed during the heating portion of the blanching process. Further, the magnitude of this variation was clearly related in a predictable fashion to the final oven set point temperature and to the dwell time at each intermediate temperature setting. Ideally, all peanuts moving through the oven should be exposed to the same air temperature treatment that has been designed to maximize blanchability. In practice, some temperature variation occurred and a number of peanuts were not exposed to the protocol temperature regime. Presentation of temperature data from all protocols is not expedient; therefore, bed top and bottom temperature for protocols no. 1 (30 min/76.7 C), no. 3 (60 min/ 76.7 C), no. 7 (30 min/98.9 C), and no. 9 (60 min/98.9 C) are depicted in Figs. 2-5, respectively, as representative of all protocols examined. Bed temperatures at other thermocouple locations within these protocols followed the same trends as those depicted and mid-bed temperatures consistently approximated the mean of the top and bottom temperature. Bed temperature data from all protocols followed a similar pattern in that within a given heating interval, peanuts on the side closest to the source of the air flow reached higher temperatures that more closely approximated the oven set point for that interval. When the air flow direction was changed, temperatures on the side previously closest to the heat dropped and then increased slowly, lagging behind the temperatures on the side now nearest the heat source. This decrease in bed temperature immediately upon changing the air-flow direction was greatest in the protocols with shorter heating times (protocols 1, 4, and 7). The decrease was minimized in protocols with longer heating times (protocols 3, 6, and 9) because the temperature difference across the bed was smaller.

A measure of the variation in bed temperatures was the maximum observed temperature difference between the top and bottom thermocouples. The largest temperature difference between the top and the bottom of the bed (17.59 C) occurred in the 30 min/98.9 C protocol and the smallest difference (8.1 C) occurred in the 60 min/76.7 C protocol. Bed temperature variation decreased as total heating time increased (Table 2, compare protocols 1 vs. 3 and 7 vs. 9). When air flow direction was reversed, the degree to which the bed temperature decreased on the side away from the air flow depended on the residence time of peanuts at each

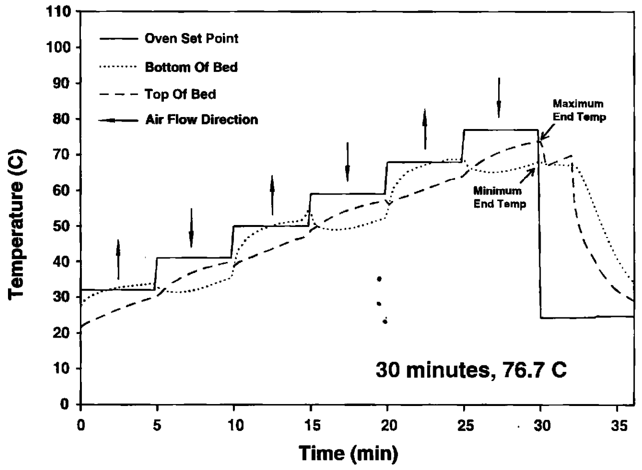

Fig. 2. Peanut bed temperatures during the 30 min/76.7 C maximum temperature blanching protocol.

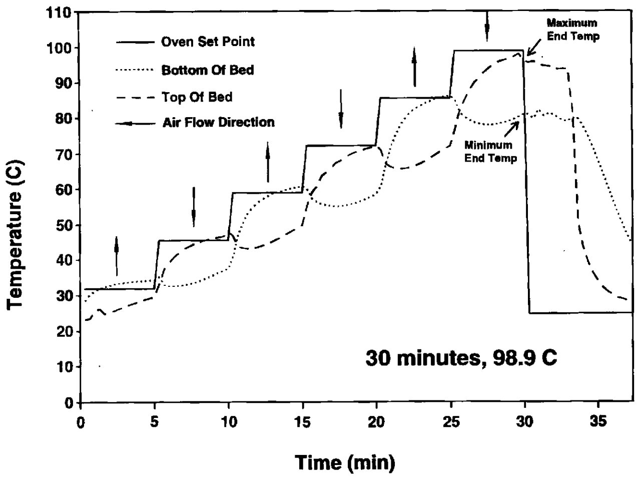

Fig. 4. Peanut bed temperatures during the 30 min/98.9 C maximum temperature blanching protocol.

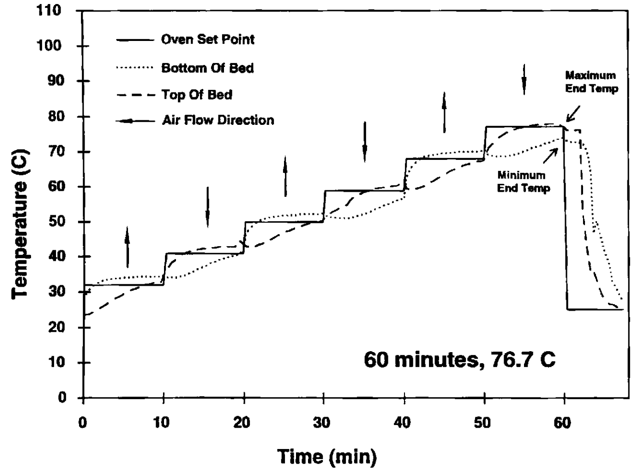

Fig. 3. Peanut bed temperatures during the 60 min/76.7 C maximum temperature blanching protocol.

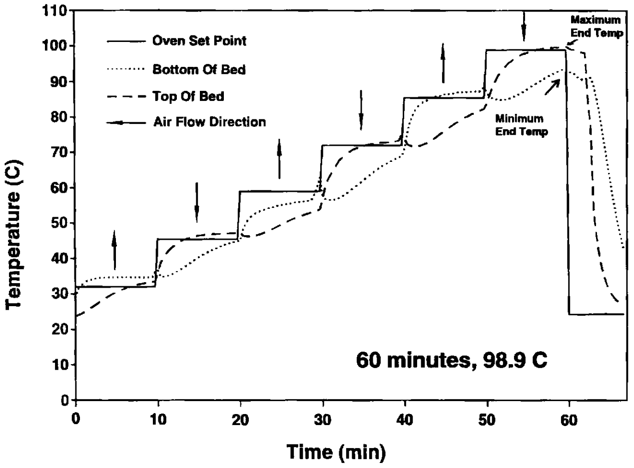

Fig. 5. Peanut bed temperatures during the 60 min/98.9 C maximum temperature blanching protocol.

temperature (i.e., total heating time). The longer the interval, the less the bed temperature decreased when air flow was reversed. As a consequence, the more evenly heated the entire bed became, the less the difference between the top and bottom thermocouple temperatures.

Maximum temperature differences between the top and bottom temperatures also increased as the final set point temperature increased (Table 2; compare protocols 1 vs. 7 and 3 vs. 9). A greater temperature gradient existed across the bed due to greater amounts of energy applied as oven set point temperatures increased. Considering the effects of oven set point temperature and heating interval length together, increasing temperatures and shorter interval lengths led to greater temperature variation within the beds. The data suggest that greater variability in bed temperatures during blanching is promoted by higher oven set point temperatures and shorter heating interval times. This was confirmed using data from all five thermocouples (Table 2) by examining the mean deviation from oven set point temperature for each protocol.

quality. The fact that temperature variation was relatively small inside the seed suggests that temperature variation in the bed affecting the temperature of entire seeds is more important than variation arising within seeds.

Moisture Content. The initial moisture content of peanuts used in the tests was approximately 5.5%. Final moisture content after heating ranged from 4.8% for the 30 min/76.6 C protocol to 2.9% for the 60 min/98.9 C protocol (Table 2). Moisture content decreases were significantly different due to increased heating time and increased oven final set point temperature. Within the parameters investigated, moisture content continued to decrease with increased heating time and set point temperature. Although Paulsen and Brusewitz (1976b) reported that the effectiveness of the blanching process was dependent on the amount of moisture removed from the peanut, these data indicated that blanchability did not increase when moisture content decreased below 3.8%.

Blanchability. Blanchability varied from 50.3% in protocol no. 1 (30 min/76.7 C) to *ca.* 75% in protocols 7-9 (Table 2). Blanchability of 75% was similar to that achieved by Farouk *et al.* (1977). Increasing heating time from 30 to 45 min increased blanchability for all set point temperatures, but increasing the time further to 60 min gave little additional increase. Blanchability correlated well with oven set point temperature (r = 0.87, P ≤ 0.001) but not with heating time (r = 0.29, P ≤ 0.252). The data suggest, that for the range of time and temperatures studied, achieving a certain cutoff temperature was more effective than longer times at less than optimal temperatures.

The Pearson correlation coefficient between blanchability and moisture content was r = 0.80. However, the relationship between blanchability and moisture content was linear only above 4% final moisture content, while below 4%, blanchability was relatively constant at *ca.* 75% (Fig. 6). Paulsen and Brusewitz (1976a,b) found that the coefficient of cubical thermal expansion of the peanut cotyledon is greater than that of the seed coat and that the difference between them is larger at lower moisture. Thus, blanchability may be the

Table 2. Maximum temperature difference, mean temperature deviation, final moisture content and blanchability in nine peanut blanching protocols.

	Protocol[a]								
Factor	1	2	3	4	5	6	7	8	9
Total heating time (min)	30	45	60	30	45	60	30	45	60
Set point temp., zone 6 (C)	76.7	76.7	76.7	87.8	87.8	87.8	98.9	98.9	98.9
Maximum top/bottom difference (C)	9.14	8.90	8.10	16.32	11.12	10.56	17.59	14.85	12.10
Mean deviation from oven set point	6.48	3.62	3.12	8.58	4.96	3.87	10.37	7.32	5.50
Moisture content (% DW)	4.81 a	4.26 b	4.00 cd	4.18 bc	3.74 e	3.30 g	3.88 ed	3.49 f	2.94 h
Blanchability (%)	50.30 g	56.30 f	58.90 e	61.10 d	72.25 bc	71.45 c	74.35 ab	75.25 a	74.55 a

[a]Means followed by the same letter within a row are not significantly different (P ≤ 0.05).

Internal Seed Temperature. Internal temperature was measured at various depths from the seed surface, ranging from 1.22 to 3.55 mm into individual peanuts. During heating, a temperature gradient developed within each seed, with the highest temperatures occurring at the seed surface (data not shown). Peanuts are approximately 50% oil, and foods high in oil generally have low thermal conductivity (Sweat, 1974; Polley *et al.*, 1980). Heat transfer into a food substance from dry air is usually slower than from hot water, hot oil, or steam (Mitchell and Malphrus, 1977; Potter, 1986). Although the high oil content suggests a relatively slow heat transfer, the internal seed temperature gradient did not exceed 5 C. Contributing factors to this limited temperature difference were the narrow width of a cotyledon (*ca.* 4 mm) and the beginning moisture content of *ca.* 5.5%.

The variation in internal temperature with respect to depth into the seed was not as large as temperature variation due to location within the peanut bed. Internal seed temperature affects the rate of moisture removal and levels of enzyme activities which may affect seed

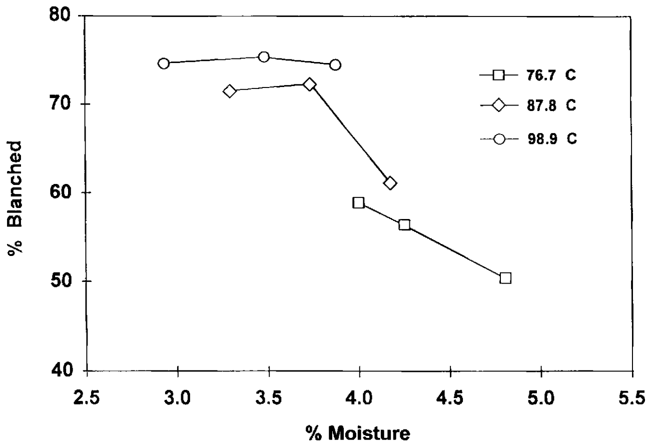

Fig. 6. Relationship of final moisture content to blanchability of peanuts in nine blanching protocols.

net result of differential thermal expansion, differences in moisture loss, or both. It is possible that alternate contraction and expansion of the seed contributes to greater blanchability. However, blanchability had no significant correlation with either the maximum top-bottom thermocouple temperature difference or with the average deviation from oven set point temperature (Table 2).

Summary and Conclusions

This study demonstrated the temperature variation that can occur in commercial peanut blanching operations. Temperature within the peanut bed varied with location and air flow direction. The magnitude of the temperature variation was related in a predictable fashion to the final oven set point and the length of time peanuts were in each heating zone. Temperature gradients were reversed when air flow direction alternated from top to bottom of the bed in successive heating zones. The study indicated that reduction in moisture content to less than 4% from a beginning moisture content of *ca.* 5.5% resulted in maximum blanching percentages of *ca.* 75%. These conditions were met only in the 45- and 60-min protocols at 87.7 C and all protocols at 98.9 C.

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