Curing Peanuts Using Continuous Flow Dryers

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Abstract. *A two-year study was conducted to determine the potential for curing peanuts using continuous flow dryers with minimal detrimental effects on quality. A single-pass continuous flow dryer and a recirculating batch dryer were compared with conventional wagon drying systems. The rate of change of peanut kernel moisture content (% w.b./h) was considerably higher in the single pass continuous flow (2.1%/h) and the recirculating batch (1.0%/h) dryers than observed in conventionally cured peanuts (0.41%/h). Peanuts cured using the single-pass continuous flow dryer had unacceptably high levels of split and bald kernels when compared to those cured in wagons. The recirculating batch dryer resulted in significantly higher percent split kernels and skin slippage. However, the reduction in peanut milling quality may be acceptable in order to achieve the faster drying rate.*

Keywords . Continuous dryers, Curing, Drying, Groundnuts, Peanut.

Peanut harvest capacity has dramatically increased during the past 10 years with no appreciable change in commercial curing (drying) equipment. Prior to 1989, peanut combines were designed to harvest one windrow (two rows) with an estimated 4 ha/day harvest capacity. Four-row combines capable of harvesting 8 ha/day were introduced around 1990. Six-row combines with a harvest capacity of approximately 12 ha/day were introduced in 1996. At least one manufacturer is now producing an 8-row peanut combine (Mathis, 1997).

During the harvest, peanuts are loaded into wagons for transport to a central location for curing and sale. These wagons have a perforated floor with a 23-cm plenum underneath and typically carry 4 to 6 t of in-shell peanuts. Most peanuts grown in the southeastern United States and the west Texas peanut production region are cured at commercial drying facilities. Under current marketing regulations, peanuts must be cured until the kernel moisture content is less than 10.5% wet basis (11.7% dry basis) before marketing (Peanut Administrative Committee, 2000). These marketing regulations make it necessary to cure peanuts in batches to maintain the identity of the peanuts until they are sold. To meet the demand for higher curing capacity and satisfy the current marketing regulations, larger batch systems have been developed and tested (Butts and Omary, 1999; Ertas et al., 1996). Some commercial drying facilities have purchased more conventional drying systems, while others have purchased larger systems using 13- to 15-m semi-trailers converted by adding a drying floor and plenum (Ertas et al., 1998). However, Blankenship et al. (2000) showed that using current peanut grading equipment, the value and quality factors could be determined at kernel moisture contents up to 25% w.b. If the change in ownership occurred prior to curing, then the handler could blend peanuts of similar quality and moisture and utilize continuous flow dryers, and possibly gain some increase in curing capacity.

To maintain optimum quality and flavor, peanuts should be cured using air heated 8 ? C above ambient, but not exceeding 35 ? C. To avoid excessive split kernels and skin slippage, the average moisture removal rate should not exceed 0.5 percentage point per hour (Beasley and Dickens, 1963). Woodward and Hutchison (1972) indicated that peanuts could be intermittently exposed to temperatures up to 54 ? C with little detrimental impact on milling quality and flavor. Noyes et al. (1997) conducted tests using a recirculating batch (RCB) dryer with intermittent exposures to air heated up to 54 ? C with minimal impact on the price paid to the farmer.

Objectives

The objective of this study was to compare continuous flow and conventional peanut dryers. Specific goals were to:

1. determine operating parameters for continuous flow or recirculating batch dryers to minimize detrimental effects on peanut quality.
2. compare the performance of a single-pass continuous flow dryer, a recirculating batch dryer, and conventional fan and wagon dryer when curing peanut.

Procedure

Tests were conducted during the 1999 and 2000 peanut harvest comparing the performance of conventional (CNV), single-pass continuous flow (CFD), and recirculating batch (RCB) dryers (figs. 1, 2, and 3, respectively). A CNV peanut dryer consists of a stationary fan and burner unit and a wagon (Peerless Mfg., Shellman, Ga.) equipped with an air plenum (fig. 1). Heated air is forced through a flexible duct, into the trailer plenum, and up through approximately 1.2 m of peanuts. The air is usually heated 8 to 12 ? C above ambient, but no higher than 35 ? C. The drying wagons are typically 4.3 or 6.4 m long. These tests were conducted using 4.3-m wagons.

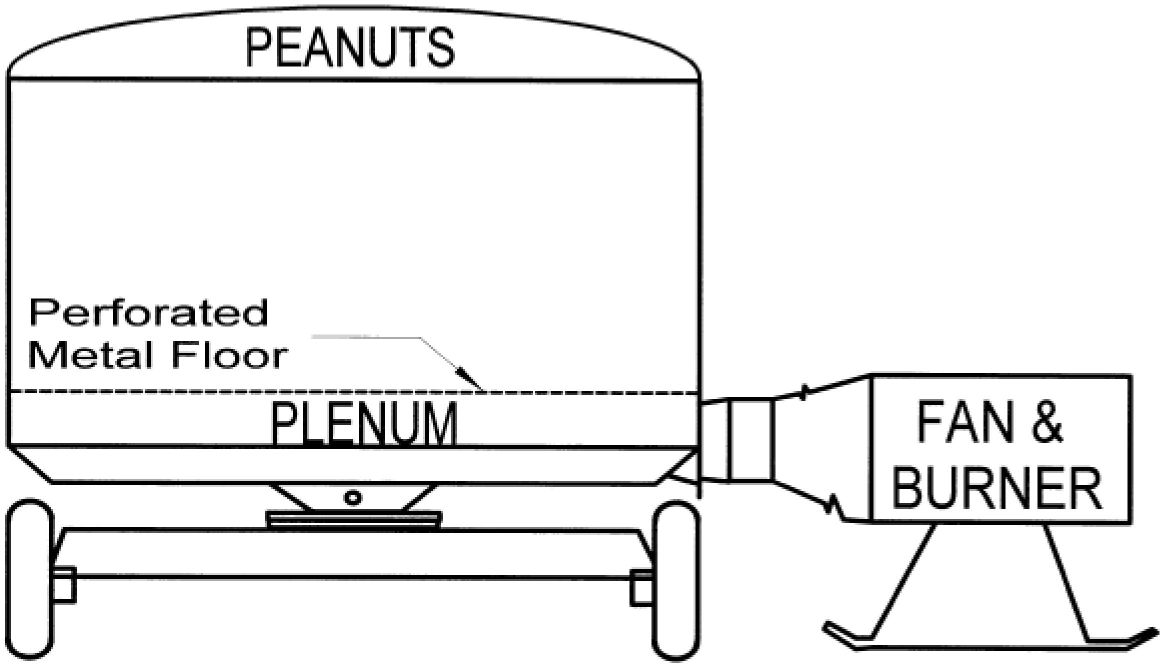

Figure 1. Schematic of a conventional (CNV) single-trailer peanut dryer.

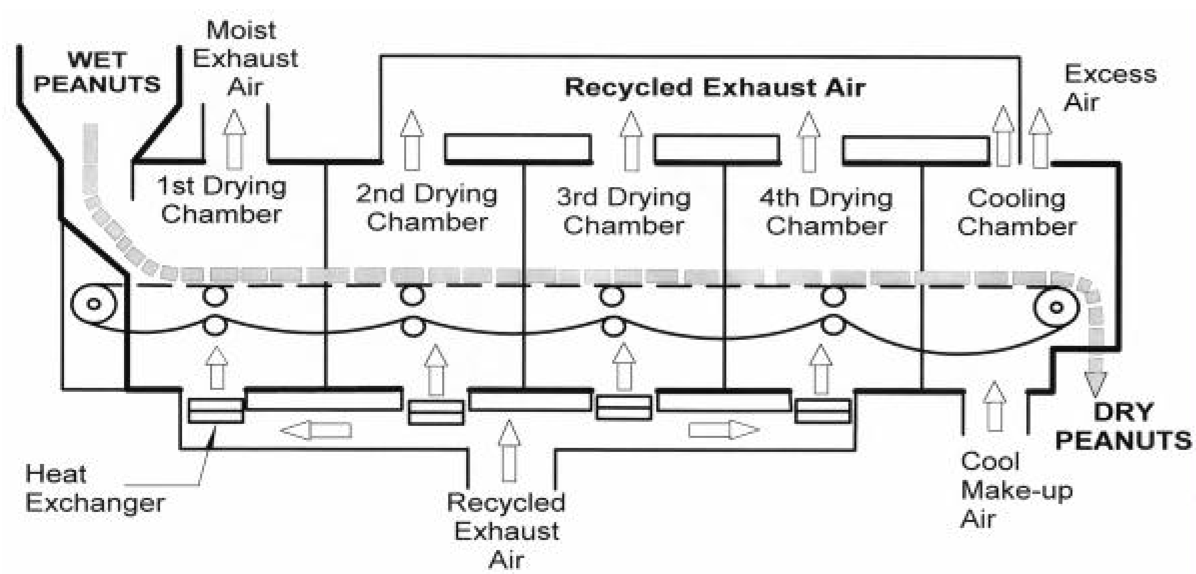

Figure 2. Schematic of continuous flow dryer (CFD) used to cure peanuts.

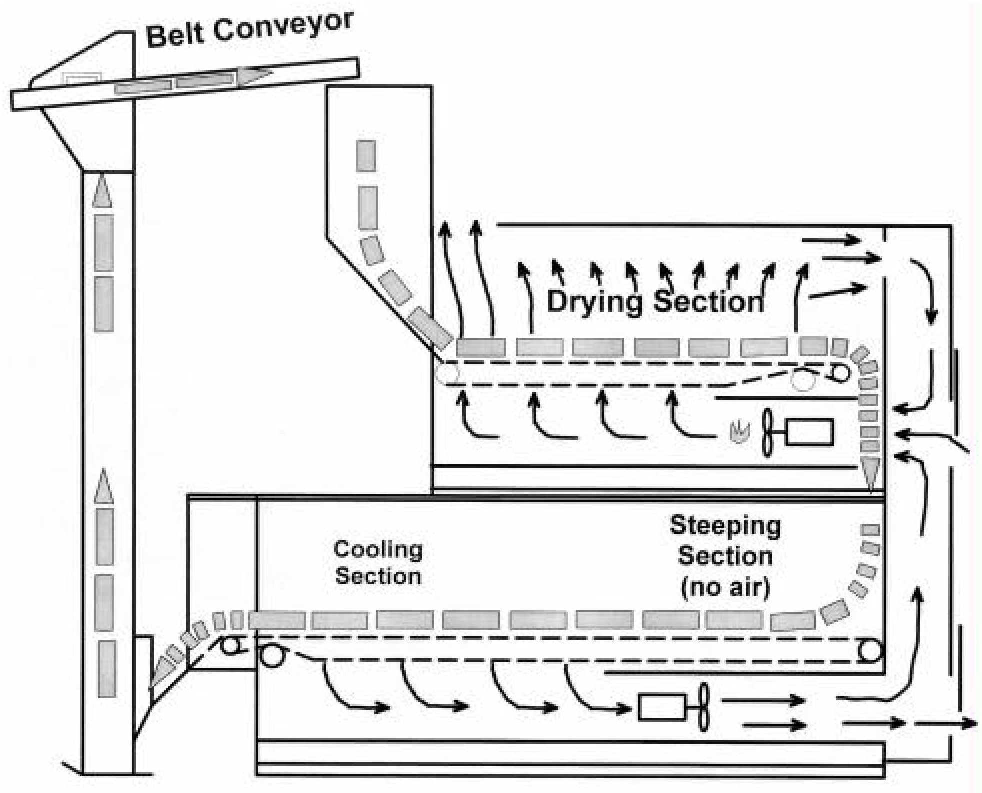

Figure 3. Schematic of recirculating batch (RCB) dryer for curing peanuts.

The CFD (Mid-State Mfg., Ripon, Calif.) was approximately 21 m long (fig. 2) and was originally designed to dry almonds. The maximum bed depth was 91 cm. There were five zones within the CFD. Four zones were heated and the fifth zone was a cooling zone. The temperature in the first four zones was constant during these tests. Air was forced up through the peanuts in each zone using a blower for each zone. Ambient air was used in the cooling zone. Air exiting the peanuts in zone 1 was exhausted to the atmosphere. However, air exhausted from the other three heating zones and the cooling zone was recirculated, mixed with ambient air, and reheated to the desired temperature for all heating zones.

The RCB dryer (BNW Industries, Mentone, Ind.) is a two-stage dryer with three different zones (fig 3). Each stage has a steel mesh conveyor approximately 1.8 m wide to convey the peanuts. In the upper stage, heated air is forced up through the peanuts. This air is partially exhausted through a 1.3- □ 1.8-m opening near the surge hopper. Part of the air is recirculated through an opening into the fan intake. The intake air for the heated section is a mixture of ambient, recirculated exhaust air from the heating section, and recirculated air from the cooling section described below. As the peanuts reach the end of the upper stage, they fall into the lower stage where the mesh web is moving in the opposite direction as the upper web. The first half of the lower stage has no forced air moving through the peanuts and is used as a steeping or tempering section. The second half of the lower stage is the cooling section and has air drawn from outside and down through the peanuts. The warm, moist air is exhausted out the open bottom of the dryer or into the intake duct for the heating fan. When peanuts reach the end of the cooling section, they fall off of the web over a vibratory screen to remove dirt and other small foreign material into the bucket elevator. The elevator and horizontal conveyor belt return, or recycle, the peanuts to the upper heated zone. Peanuts circulate through the dryer until the moisture content of the peanut kernels exiting the cooling zone reaches 11% w.b. The horizontal conveyor is reversed, unloading the peanuts into a wagon positioned underneath the spout.

During 1999, tests were conducted in California and Georgia to determine the range of acceptable control parameters for the CFD and RCB dryers. During the 2000 harvest, tests were conducted in Georgia using the RCB and CNV dryers. Peanut, *Arachis hypogea L.* , was grown and harvested according to normal production practices. Peanuts were loaded into wagons and transported to the curing facility. Data recorded during each test included initial and final moisture contents, drying time, and fuel consumption. Three 12-kg samples were obtained from each dryer and shelled using a rotary peanut sheller that simulates the aggressiveness of commercial peanut shelling equipment (Davidson and McIntosh, 1973). Peanut milling quality (McIntosh et al., 1971) and seed germination was determined for shelled peanuts from each sample. Analysis of variance tests (paired t-tests, SAS, Inc) were used to detect differences between mean indicators of peanut quality.

California Tests

Spanish-type peanuts grown near Kettleman City, California, by Sandridge Partners, Inc. were dug 23 September 1999 and allowed to partially cure in windrows. Peanuts were harvested on 28 September 1999 and placed in five peanut drying wagons and transported from the field. Three 12-kg samples were obtained, placed in mesh bags, and buried 10 to 15 cm below the surface of the peanuts in one wagon. This wagon was connected to a conventional fan and burner unit and cured using air heated 8 ? C above ambient, but no higher than 35 ? C. Peanuts in the remaining four wagons were transferred into a hopper-bottomed semi-trailer and transported approximately 100 km to Central Valley Almond Association (CVAA) in McFarland, California. Upon arrival at CVAA, peanuts were unloaded from the trailers and loaded into the CFD. Three 12-kg samples were obtained as peanuts were unloaded from the trailer into the CFD and placed in mesh bags. Using an access window, the samples were placed on top of the peanuts as they moved through the dryer. A second test using the CFD was conducted using peanuts harvested 29 September. Peanuts were not available for the conventional dryer during the second test. A third test was planned, but the peanut moisture content when harvested was already at a marketable moisture. Therefore, three 12-kg samples were obtained from this load of field-cured (FLD) peanuts for comparison to the samples from CNV and CFD dryers.

Prior to curing, a data logger (HOBO Pro, Onset Computers, Bourne, Mass.) was placed in each sample bag to record temperature and relative humidity every 5 min. Initial and final kernel moisture content was determined using a single kernel moisture meter (CTR-160P, Shizuoka Seiki Co., Ltd., Shizuoka, Japan). Drying time for the CFD was determined by measuring the time required for the peanuts to travel the length of the dryer at the test depth. Natural gas or propane consumption was recorded for each dryer using in-line meters.

Georgia Tests

Runner-type peanuts grown by farmers in the three-county area surrounding Dawson, Georgia were used in these studies. Peanuts were grown and harvested according to conventional practice. Two conventional drying wagons were filled with peanuts by cooperating growers and transported to the USDA-ARS, National Peanut Research Laboratory for testing. One wagon was cured using a conventional dryer. Air was heated using a constant thermostat setting of 35 ? C. Three 12-kg samples were obtained as peanuts were loaded into the trailer in the field and buried approximately 12 cm in the load of peanuts. Smaller samples were obtained periodically throughout the curing process to monitor the peanut kernel moisture content. A probe with three data loggers was inserted vertically down into the peanuts at the center of the wagon to record temperature and relative humidity every 15 min at the bottom, middle, and top of the load of peanuts. Data loggers were also mounted on the dryer inlet and in the plenum.

Peanuts from the second wagon were transferred into the RCB dryer. Periodically, small samples were obtained as the peanuts exited the cooling section of the dryer for moisture content analysis. Once the moisture content reached approximately 11% w.b., they were unloaded from the dryer and three 12-kg samples obtained as peanuts exited the unloading spout into the wagon.

Initial and final moisture contents were determined using a single kernel moisture meter, a bulk moisture meter (GAC 2000, Dickey-john, Auburn, Ill.), and the oven method (ASAE, 1997). Intermediate kernel moisture measurements were obtained using the GAC 2000 only.

These paired tests were repeated three times during the 1999 harvest and five times during 2000.

Results and Discussion

California Results

Bed depth and initial moisture content were the primary variables when curing Spanish peanuts in the CFD (table 1). The average ambient temperature during the tests was 31 ? C and ranged from 24 to 35 ? C. The relative humidity averaged 9% and ranged from 4 to 13%. The plenum temperature of the CFD averaged 76 ? C. During Run 1, peanuts were approximately 61 cm deep and the belt speed was 0.9 m/h. Based on the dry weight of peanuts and the total time required for peanuts to move through the dryer, the drying capacity for Run 1 was 1.5 t/h. The peanuts from Run 1 were dried from 22 to 11% moisture content. During Run 2, peanuts were dried from 16 to 10% moisture content using a 91-cm bed depth and an approximate belt speed of 2.7 m/h, resulting in a drying capacity of 5.8 t/h. Peanuts were cured in the CNV dryer using an average plenum temperature of 35 ? C to reduce the kernel moisture content from 20 to 10%. Based on an approximate peanut dry weight of 4.5 t, the drying capacity of the conventional dryer was 0.4 t/h. Peanuts cured naturally in the windrow to 11% moisture content in approximately six days.

Table 1. Summary of peanut curing trials conducted during 1999 using continuous flow (CFD), recirculating batch (RCB), and conventional (CNV) dryers.

Location	Dryer	Test	Moisture	Final	Dryer	Bed	Curing	Drying

			Content (w.b.)		Peanut Mass (kg)	Temp. [a] (? C)	Depth [b] (cm)	Time (h)	Rate [c] (%/h)
			Initial	Final					
CA	CNV	1	19.8	10.3	N/A	34.7	130	11	0.86
	CFD	1	22.0	11.4	11020	76.5	61	7	1.51
		2	16.0	10.4	14020	76.5	91	2	2.80
	FLD	3	N/A [d]	11.0	N/A	N/A	N/A	~144	N/A
GA	CNV	1	11.5	10.6	N/A	36.7	130	3	0.30
		2	17.3	10.4	N/A	29.2	130	27	0.25
		3	23.5	9.6	5340	33.8	130	31	0.45
	RCB	1	12.8	10.2	N/A	40.8	31/91	2	1.30
		2	20.5	11.1	N/A	34.7	31/91	14	0.67
		3	22.7	10.4	5180	52.4	31/91	11	1.12

[a] Dryer temperature is average air temperature in heated plenum.

[b] Bed depth in heating and steeping/cooling sections of RCB dryer separated by slash.

[c] Drying rate calculated by dividing the difference between initial and final moisture content by the drying time (%/h).

[d] Data not available or not applicable.

The single kernel moisture distribution of Spanish peanuts when first harvested and prior to mechanical curing was relatively uniform (fig. 4). The distribution of individual kernel moisture contents of peanuts cured using the conventional dryer in California became more normally distributed with a definite peak (fig. 4). However, the single kernel moisture distribution of peanuts cured using the CFD remained approximately the same shape as the initial distribution, but was shifted toward lower moistures (fig. 4). The parallel slopes of the initial and final cumulative frequency distributions (fig. 5) indicate that the standard deviation of moisture contents did not change appreciably. Initially, the peanuts had an average single kernel moisture content of 19.8 and 66% of the kernels had a moisture content of at least 15% (fig. 5). As the peanuts exited the CFD, 28% of the peanuts had moisture contents greater than or equal to 15%. According to Diener et al. (1982), the risk for aflatoxin contamination during storage is considerable if the seed moisture content remains above 15% for as little as three days.

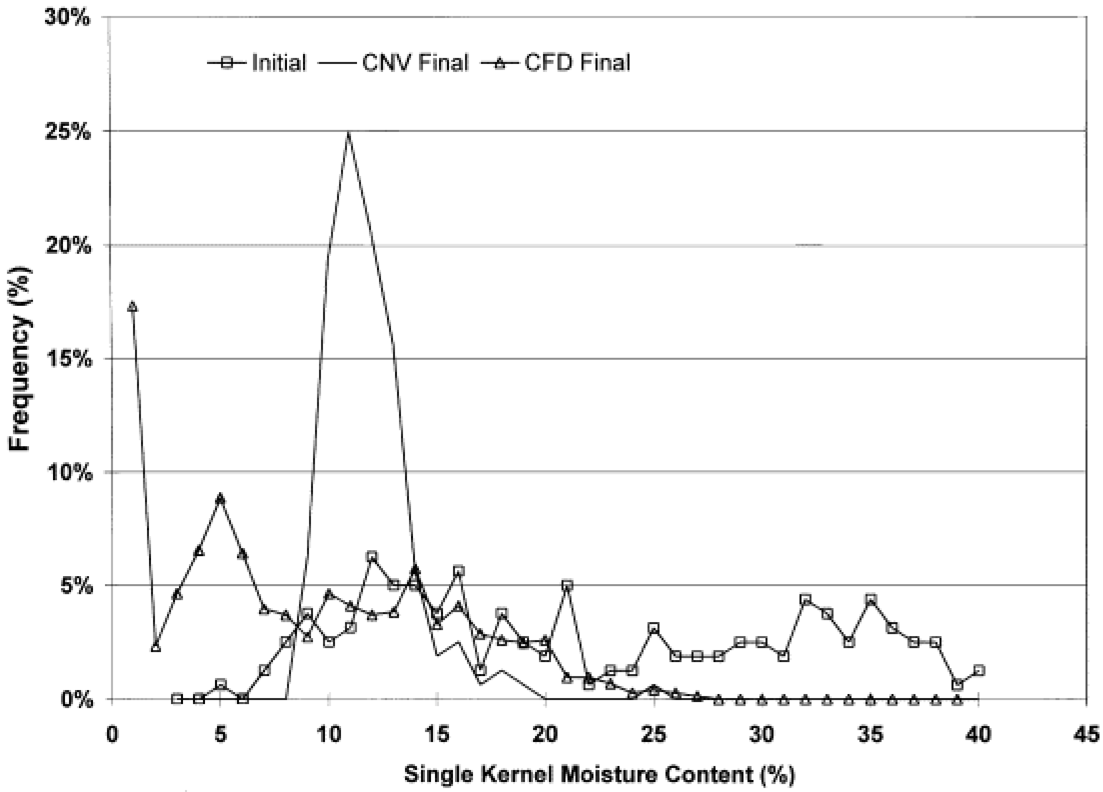

Figure 4. Frequency distribution of the single kernel moisture content of Spanish peanuts before and after curing in conventional (CNV) and continuous flow (CFD) dryers.

The single kernel moisture distribution obtained in the conventional dryer is more desirable for subsequent storage and handling than the distribution obtained in the CFD. The frequency distribution of the single kernel moisture of peanuts cured in the CNV dryer (fig. 4) showed a marked decrease in the average kernel moisture as well as a decreased standard deviation. The cumulative frequency distribution (fig. 5) showed that only 6% of the conventionally cured peanut kernels exceeded 15% moisture content. The risk of aflatoxin contamination during storage of the conventionally cured peanuts was considerably lower than those cured in the CFD. The peanuts cured in the CFD may equilibrate to a moisture profile similar to that obtained with the CNV dryer, but equilibration would occur in storage where the moisture would have to be removed by the warehouse ventilation system.

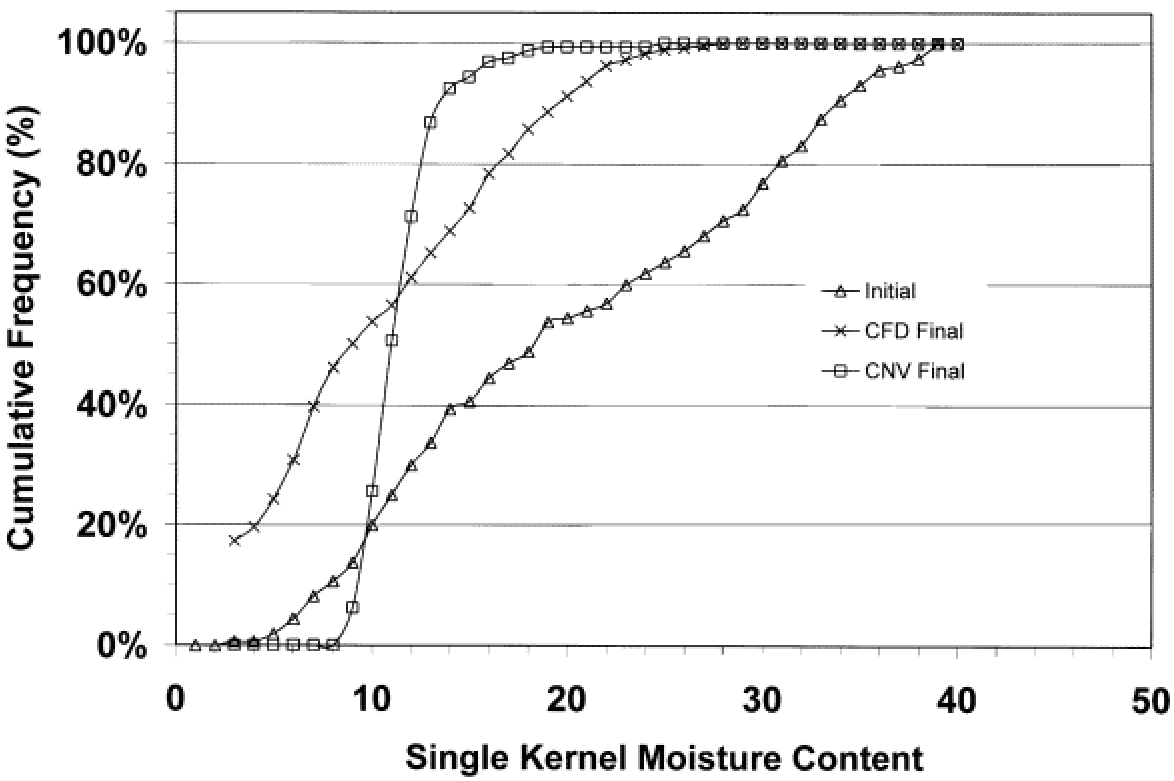

Figure 5. Cumulative frequency distribution of single kernel moisture content of Spanish type peanuts cured using conventional (CNV) and continuous flow dryers (CFD).

Peanut value is determined by the kernel size distribution within commercial size categories (table 2, USDA, 1993) and varies somewhat according to peanut type. Price is generally higher for larger kernels. Depending on the market, split kernels are usually priced about the same as medium-sized kernels. The kernel size distribution, percent splits, bald kernels, flavor, and germination combined are referred to as milling quality. Excessive moisture removal rates, high temperatures, and mechanical damage can reduce milling quality. Skin slippage usually occurs during the shelling process and a peanut kernel without the skin is commonly referred to as a bald kernel. More than 1.5% bald kernels are undesirable because they will usually split during handling. Also, many coatings will not adhere to the bald kernel. Off-flavors caused by high temperatures during the drying process are indicated by a fruity-fermented aroma or flavor.

Table 2. Commercial U.S. kernel size categories for runner, Spanish, and Virginia peanut market types.

Kernel Size	Peanut Market Type		
	Runner mm (in.)	Spanish mm (in.)	Virginia mm (in.)

Extra Large Kernel (ELK)	N/A	N/A	> 8.1 □ 25.4 slot (20 ?/64 □ 1 slot)
Jumbo	> 8.3 □ 19.1 slot (21/64 □ ? slot)	> 8.3 □ 19.1 slot (21/64- □ ?-in.slot)	N/A
Medium	> 7.1 □ 19.1 slot (18/64 □ ? slot)	N/A	> 7.1 □ 25.4 slot (18/64 □ 1 slot)
Number One	> 6.3 □ 19.1 slot (16/64 □ ? slot)	> 6.3 □ 19.1 slot (16/64 □ ? slot)	> 6.0 □ 25.4 slot (15/64 □ 1 slot)
Splits	> 6.7 round (17/64 round)	> 6.7 round (17/64 round)	> 6.3 round (16/64 round)
Oil Stock	< 6.7 round (17/64 round)	< 6.7 round (17/64 round)	< 6.3 round (16/64 round)

The Spanish-type peanuts cured in the CNV dryer had less jumbo-sized kernels and more number one-sized kernels than those peanuts cured using the CFD (table 3). The percent of oil stock in peanuts cured in the CNV dryer was greater than those peanuts cured in the CFD and in the FLD. However, the total percent kernels were not significantly different for the different curing methods and averaged 69.7%. Peanuts cured using the CFD had significantly higher percent of split kernels (7.8%) than those cured in the CNV dryer (4.1%) and in the FLD (5.0%). Bald kernels were significantly less in peanuts cured using the CNV dryer (1.5%), than in peanuts cured using the CFD (7.1%). The percent bald kernels found in FLD cured peanuts were not significantly different from those cured using the CNV dryer.

Table 3. Summary of quality of Spanish peanuts cured using conventional (CNV), continuous flow (CFD), and field (FLD) curing in California during 1999.

Quality Parameter	Curing Method [a]		
	CNV	CFD	FLD
Kernel size distribution [b]			
Jumbo	22.2 b	25.2 a	25.4 a
Ones	33.7 a	29.8 b	32.8 a
Splits	4.1 c	7.8 a	5.0 b
Oil Stock	10.3 a	7.3 b	7.0 b

Bald kernels [c]			
Jumbo	3.1 b	15.5 a	6.7 b
Ones	2.5 b	10.9 a	4.5 b
Total	1.5 b	7.1 a	3.2 b
Seed Quality			
Germination (%)	90.0 a	50.0 b	93.2 a

[a] Means in the same row followed by the same letter are not significantly different (a = 0.05).

[b] Presented as percentage of total pod mass.

[c] Presented as percentage of mass in each kernel size category; Total presented as percentage of all edible kernels including splits.

The seed germination rates were very high in those peanuts cured in the FLD and CNV dryer. Seed germination rates averaged 93.2 and 90.0%, respectively. These germination rates were significantly higher than the 50.0% germination rate of peanuts cured using the CFD.

Drying rates and dryer capacity for the CFD were significantly higher than those achieved with the CNV dryer and FLD. However, the resulting milling quality was undesirable.

Georgia Results

1999 Tests

Based on the results obtained in the California tests, dryer temperatures were varied in the RCB dryer to determine an upper limit on the acceptable heated air temperature for the continuous flow drying process. Laboratory scale tests by Woodward and Hutchison (1972) indicated that 52 ? C might be the maximum intermittent temperature that will result in acceptable peanut quality. Three paired tests were completed where the plenum temperature in the RCB dryer were 41, 35, and 52 ? C.

The initial moisture content of peanuts cured in the RCB dryer tended to be slightly higher than those cured in the CNV dryer (table 1), but the final moisture contents were approximately the same. In general, the RCB dryer cured peanuts in approximately half the time required to cure in the CNV dryers. When the higher plenum temperature was used in the RCB dryer, the time required to reach the desired final moisture was approximately one-third of the time required in the CNV dryer.

The distributions of single kernel moisture content of peanuts were similar for the CNV and RCB dryers (fig. 6). Initially, 58% of the peanut kernels had a moisture content of 15% or more. After curing, 8% of the kernels cured in the RCB dryer were at least 15% compared to only 4% of the kernels cured conventionally.

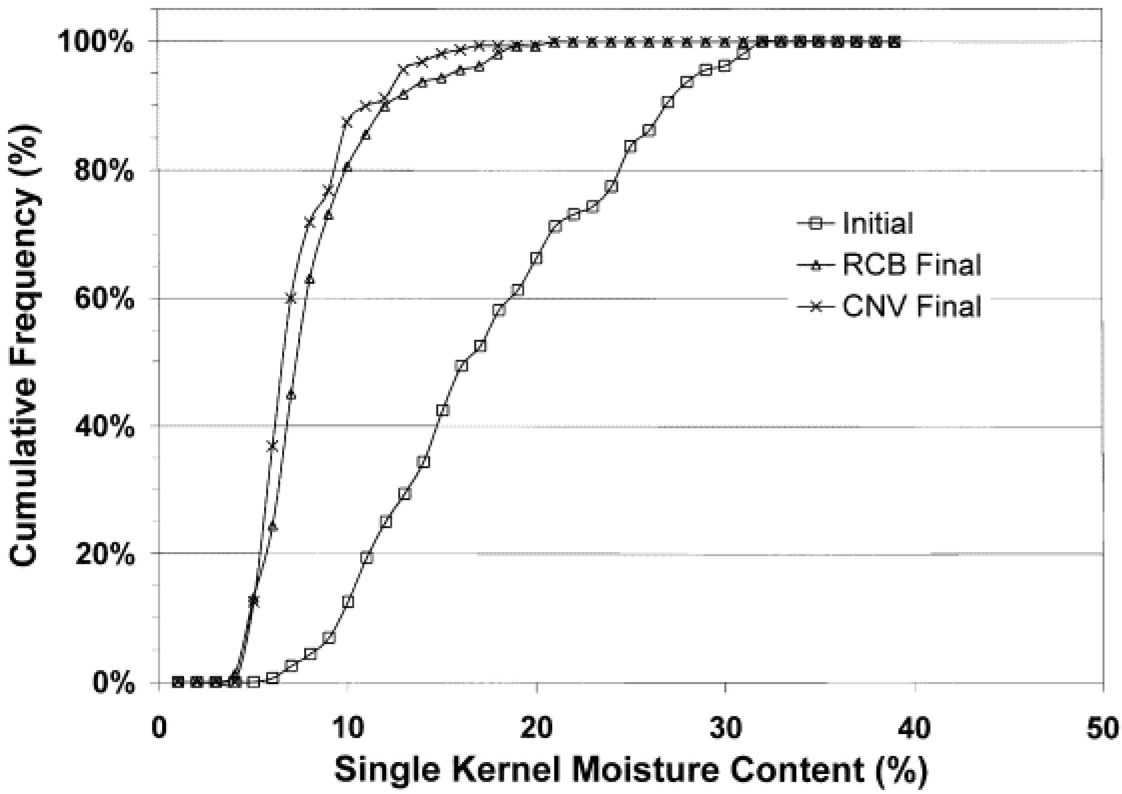

Figure 6. Cumulative frequency distribution of single kernel moisture content of runner-type peanuts cured using conventional (CNV) and recirculating batch (RCB) dryers.

There were no significant differences in milling quality for peanuts cured conventionally and those cured in the RCB dryer using a plenum temperature of 41 or 35 ? C (table 4). However, when the plenum temperature was increased to 52 ? C, the splits and bald kernels were significantly higher than those peanuts cured conventionally. The splits increased to 18.7% compared to 8.8% and the bald kernels were 8.1% compared to 0.1%. Seed germination also dropped from 84.3 to 69.3% in peanuts cured in the RCB at 52 ? C, but was not significantly different.

Table 4. Summary of quality of runner type peanuts cured in Georgia using conventional (CNV) and recirculating batch (RCB) dryers during 1999 .

Quality Parameter	Test 1				Test 2				Test 3		
	CNV	RCB	P > t		CNV	RCB	P > t		CNV	RCB	P > t
Jumbo (%)	19.1	16.1	0.283		12.6	14.0	0.414		35.9	30.9	0.322
Medium (%)	34.9	37.9	0.313		44.3	40.8	0.130		25.4	20.9	0.275
Ones (%)	5.7	5.6	0.943		7.9	7.9	0.993		5.8	4.1	0.179
Splits (%)	9.1	9.8	0.349		7.6	8.8	0.331		8.8	18.7	0.005

Other kernels (%)	5.4	5.7	0.816		4.3	6.7	0.183		3.2	4.4	0.240
Bald kernels (%)	0.5	0.6	0.620		0.3	0.4	0.160		0.1	8.1	0.001
Germination (%)	92.0	88.0	0.373		90.3	90.0	0.807		84.3	69.3	0.256

2000 Tests

Based on results from the 1999 tests and previous research, five batches were cured during the 2000 harvest using a constant 43 ? C plenum temperature in the heated section of the RCB dryer. The average temperature of the cooling air was 18 ? C. The plenum temperature in the CNV dryer averaged 35 ? C and the ambient air temperature averaged 22 ? C.

The initial moisture content for the CNV and RCB dryers were 21.8 and 21.9%, respectively, but were not significantly different (table 5). The final moisture contents were not significantly different and averaged 11.0 in the CNV dryer and 10.4% in the RCB dryer. However, the standard deviation of the single kernel moisture content after drying was significantly lower in peanuts cured using the RCB dryer. The moisture removal rate from peanuts cured in the RCB dryer was approximately 65% higher than the CNV dryer. The moisture removal rate averaged 55.3 kg/h using the RCB dryer compared to 33.6 kg/h with the CNV dryer. The propane consumption for each batch averaged 120 L using the RCB dryer and 111 L using the CNV dryer, but was not significantly different. The RCB dryer used approximately 33% more electricity than the CNV dryer for each batch. Based on the dry mass of each batch and the total drying time, the drying capacity of the RCB dryer was 75% higher than the CNV peanut drying system.

Table 5. Comparing performance of conventional (CNV) and recirculating batch (RCB) dryers for curing runner type peanuts during 2000 harvest in Georgia.

	CNV	RCB	Pr =?t?
Moisture Content (% w.b.)			
Initial single kernel avg.	21.8	21.9	0.952
Final single kernel avg.	11.0	10.4	0.103
Final single kernel std. dev.	4.2	3.0	0.031
Drying time (h)	22.3	15.0	0.010
Moisture removal rate			
(%/h)	0.38	0.67	0.002
(kg/h)	33.6	55.3	0.039
Energy consumption			
Propane (L)	111	120	0.270
Electricity (kWh)	87	116	0.002

Drying capacity			
Peanut throughput (t/h)	0.21	0.37	0.014
Moisture removal rate (kg/h)	33.6	55.3	0.039

Since the RCB dryer uses a bucket elevator to recirculate peanuts from the outlet of the cooling section to the surge hopper of the drying section, additional mechanical damage may occur. Mechanical damage can be measured by the percent of peanuts shelled during the harvest and drying process. The percent loose-shelled kernels (LSK) may increase if excessive handling occurs. The LSK were 0.6 percentage points higher in peanuts cured using the RCB dryer than in the CNV dryer.

The outlet of the cooling section of the RCB dryer had a vibratory screen to remove some of the dirt and small rocks during the drying process. The percent foreign material found in the peanuts from the RCB dryer was slightly lower than the CNV dryer, but was not significantly lower.

The only significant difference found in the distribution of whole kernels was in the jumbo-sized kernels (table 6). The percent of jumbo-sized peanuts in those cured using the RCB dryer was 2 percentage points lower than those cured using the CNV dryer. Though not significant, the percent of medium-sized kernels was also lower. The total decrease in jumbo- and medium-size kernels was approximately the same as the increase in percent of split kernels. Peanuts cured using the RCB dryer had 10.7% splits compared to 7.6% for conventionally dried peanuts. Peanuts cured using the RCB dryer had 1.6% bald kernels versus 0.1% in conventionally dried peanuts. There were no significant differences in seed germination.

Table 6. Peanut quality for runner type peanuts cured using conventional (CNV) and recirculating batch (RCB) dryers during 2000 in Georgia.

Quality Parameter	Dryer		P > ?t?
	CNV	RCB	
Foreign material (%)	5.5	4.9	0.427
Loose shelled kernels (%)	1.6	2.2	0.005
Moisture content (% w.b.)	6.3	6.1	0.288
Kernel distribution			
Jumbo (%)	19.1	17.1	0.070
Medium (%)	37.3	36.5	0.331
No. 1 (%)	8.2	8.1	0.939
Splits (%)	7.6	10.7	<0.001
Oil stock (%)	3.5	3.5	0.986
Bald kernels (%)	0.1	1.6	<0.001

Germination (%)	84.9	84.3	0.856

Conclusion

A two-year study was conducted to determine the operating parameters for continuous flow dryers for farmer?s stock peanuts. Peanuts can be successfully cured using continuous flow dryers, however, some reduction in quality should be expected. These tests using prototype dryers, yielded results similar to laboratory tests conducted by others. Continuous exposure of peanuts to high temperatures resulted in unacceptable levels of split and bald kernels as well as reduced seed germination. Using intermittent exposure to elevated drying temperatures up to 43 ? C resulted in higher drying rates than conventional, and also increased split and bald kernels. Fossil fuel consumption for the recirculating batch dryer was not significantly higher than the conventional peanut dryer, however, the electrical consumption was. Therefore, operating costs for the recirculating batch dryer would be higher than for the conventional dryer. A continuous flow dryer with heating, steeping, and cooling sections is a viable alternative to conventional peanut drying systems. However, the equipment will cost considerably more than the equivalent capacity of wagon drying systems. When considering a continuous flow drying system for peanuts, the higher drying capacity in the continuous flow dryer must be weighed against the decreased milling quality, the higher initial capital expenditure, and the overall operating costs

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REFERENCES

ASAE Standards , 44th Ed. 1997. S410.1 Moisture measurement-peanuts. St. Joseph, Mich.: ASAE.

Beasley, E. O. and J. W. Dickens. 1963. Engineering research in curing peanuts. N.C. Agric. Exp. Sta. Bull. No. 155. Raleigh, N.C.: North Carolina State Univ.

Blankenship, P. D., M. C. Lamb, C. L. Butts, T. B. Whitaker, and E. J. Williams. 2000. Summary report on grading high moisture farmer stock peanut lots. Alexandria, Va.: Amer. Peanut Council.

Butts, C. L., and M. Omary. 1999. Feasibility tests for a two-stage batch dryer for curing farmer stock peanuts. *Peanut Sci.* 26(2): 68-73.

Davidson, J. I., Jr., and F. P. McIntosh. 1973. Development of a small laboratory sheller for determining peanut milling quality. *J. Amer. Peanut Res. Educ. Assoc.* 5(1): 95-108.

Diener, U. L., R. E. Pettit, and R. J. Cole. 1982. Aflatoxin and mycotoxins in peanuts. In *Peanut Science and Technology* , eds. Pattee, H. E., and C. T. Young, 486-519. Yoakum, Tex.: Am. Peanut Res. Educ. Soc.

Ertas, A., W. T. Fair, C. Butts, and B. T. Tanju. 1996. A new design concept for an automated peanut processing facility. *Proc. 2nd World Conf. On Integrated Design and Process Technology* , 3:197-201. Austin, Tex.: Soc. Design and Process Sci.

Ertas, A., S. Firenza, B. T. Tulu, O. Culvaci, T. T. Maxwell, M. Schubert, R. Henning, and C. Butts. 1998. Design and development of a new peanut curing process for west Texas. *Drying Technology* 17(6): 1149-1159.

Mathis, M. 1997. Personal communication. Sales Manager, Amadus Industries, Albany, Ga. 9 May 1997.

McIntosh, F. P., J. I. Davidson, Jr., and R. S. Hutchison. 1971. Some methods of determining milling quality of farmers? stock peanuts. *J. Amer. Peanut. Res. Educ. Assoc.* 3(1): 43-51.

Noyes, R. T., J. Criswell, and C. Butts. 1997. Field drying research on the recirculating batch peanut dryer. Peanut Research at OSU, Oklahoma State Univ.

Peanut Administrative Committee. 2000. Marketing agreement for peanuts. No. 146. Regulations and Instructions. Peanut Administrative Committee, Albany, Ga.

USDA. 1993. Milled peanuts (Shelled stock and cleaned Virginia type in the shell) Inspection Instructions. U.S. Dept. Agric., Agric. Marketing Svc., Fruit and Vegetable Div., Washington, D.C.

Woodward, J. D., and R. S. Hutchison. 1972. Drying farmers? stock peanuts with intermittent exposures to heated air. USDA, ARS, Marketing Research Report No. 933. U.S. Department of Agriculture. Washington, D.C.: USDA.