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Potential for Direct Harvesting of Peanuts [1]

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ABSTRACT

The concept of harvesting peanuts has remained the same since the windrow-harvesting method replaced stack-pole harvesting. The purpose of this paper is to state the present position on conventional peanut harvesting and discuss the potential for direct harvesting of Virginia-type peanuts.

The field operations for the conventional and direct-harvesting methods are compared. Advantages and disadvantages of each harvesting method as they relate to peanut losses and peanut damages are discussed. The operational performance and evaluation of the direct harvester developed at Suffolk, Va., is presented. The importance of the drying operation for the conventional and direct-harvesting methods is discussed relative to cost of drying, managing the drying operation, and improving thermal efficiency.

Key Words: Peanuts, Harvesting, Drying, Losses, Damages

In the late fifties and early sixties windrow harvesting of peanuts began to replace stack-pole harvesting in the Virginia-Carolina area (2, 6). Although significant improvements have been made in the digging, combining, and drying equipment, the basic harvesting concept has remained the same.

Continuing problems associated with windrow harvesting are the timing of harvest, weather risk, pod damage, drying efficiency, and seed and edible qualities after drying. Some of these problems, such as the weather risk, can be reduced by the direct harvesting of peanuts.

Mills (7) initiated research on the concept of green-harvesting Virginia bunch peanuts, i. e., digging and picking in one pass through the field. In 1969, the USDA (1) began research on direct green-harvesting of Virginia-type peanuts at Tifton, Ga., and Suffolk, Va. This approach has several advantages, particularly for the Virginia-North Carolina peanut-growing area.

The purpose of this paper is to state the present position on conventional peanut harvesting and discuss the potential for direct harvesting of Virginia-type peanuts. The discussion includes a description of research efforts in Virginia on a direct-harvesting system.

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Results and Discussion

Peanut Harvesting Systems

The peanut production system can be divided into three categories, production, harvesting, and marketing. Only the harvesting aspects are discussed here.

The harvesting process includes the digging, combining, and drying operations. This process begins when the peanuts are ready to be dug, and ends when the peanut moisture content has been reduced to a safe storage level.

Conventional harvesting system. In conventional harvesting, the plant and peanuts are first dug or separated from the soil. Two rows of plants are placed in an inverted windrow to expose the peanuts to the sun. The peanuts are left in the windrow until they have partially dried to a moisture content of 25 or 35 percent. This usually takes 4 to 7 days. After this interval of time, risk of loss from adverse weather greatly increases, and the rate of drying in the windrow decreases.

In the digging operation, peanut losses are affected by the timing of the operation, physical condition of the vines, soil moisture, peanut cultivar, and equipment condition and operation. Peanut losses from normal digging dates may range from 6 to 20 percent (3) of the recovery yield. The magnitude of these losses and the variability of the recovered yield by digging date are presented in Tables 1 and 2.

Table 1. Effect of digging date on digging loss as percent of recovery yield for conventional harvesting of peanuts.

	Digging Loss (percent)		
Digging Date[1]	1967	1968	1969
9/28 ± 3 days	13	7	14
10/12 ± 3 days	18	13	30
10/26 ± 3 days	22	33	77

1 Digging dates are approximate. Source: Annual Report, Peanut Harvesting and Drying, USDA, SEA, Suffolk, Va.

Table 2. Effect of digging date on recovered yield for conventional harvesting of peanuts.

	Yield (kg/ha)		
Digging Date[1]	1967	1968	1969
9/28 ± 3 days	3243	3755	3735
10/12 ± 3 days	3651	3970	3488
10/26 ± 3 days	3959	3643	2623

1 Digging dates are approximate. Source: Annual Report, Peanut Harvesting and Drying, USDA, SEA, Suffolk, Va.

Within the last 2 years an operation called vine lifting or fluffing has been used extensively on the inverted windrow. This operation is similar to reshaking, but it does not destroy the inverted-windrow orientation. Vine lifting for soil removal is most effective when done within 2 days of digging. Losses are minimal when vines and pegs are in a wilted condition. If windrow-drying conditions are poor, the vine lifter may be used to break the soil-leaf interface several hours before combining. The leafy plant material can then dry and provide better vine conditions for combining. No field loss data are available for the lifting operation.

Conventional combines employ the all-cylinder picking principle. Even though the pickup mechanisms and cylinder diameters vary between models, the threshing action of shredding the vines for peanut-plant separation is similar.

Depending on capacity and vine conditions, these machines are pulled through the field at 2.4 to 6.4 km/hr (1.5 to 4 mph). One windrow is picked up, and the peanuts are separated from the plant material and placed in a bulk container. The plant material is returned to the soil surface in a shredded condition. From the bulk containers the peanuts are dumped into drying trailers or trucks and are moved to the drying facilities.

With the conventional harvesting system, two or three passes through the field are required, a lapse of time between digging and combining is necessary, and peanut losses and damage are inevitable. Each pass through the field requires time and energy, which may result in quality and yield losses. The possibility of an early frost is always a threat because the harvesting season begins within 6 weeks of the average frost date.

Studies in Virginia (9) showed that 20 to 30 percent of the peanuts harvested with a conventional combine had visibly damaged pods. The percent of loose-shelled kernels (LSK) was low for peanuts harvested at an intermediate moisture content. Subsequent shelling damage increased and germination percentage decreased with an increase in moisture content at harvest. Invisible pod damage (detected by fast green dye technique) in hand-picked peanuts increased with exposure time in the windrow. Peanuts lost from the rear of the combine ranged from 4 to 6 percent of the harvested yield.

Turner et al. (8) determined the effect of impact on seed germination and subsequent shelling damage by controlling peanut moisture content, impact velocity, and pod orientation at impact. Peanut damage increased rapidly as the impact velocities exceeded 9.1 m/s (1800 fpm). Relative velocities between the cylinders in conventional combines range from about 12.7 to 15.2 m/s (2500 to 3000 fpm).

Average grade data for farmers stock peanuts harvested conventionally are presented in Table 3. Two factors, sound splits (SS) and LSK, indicate how the peanuts are handled during the combining and drying operations. Data for SS and LSK for the last 6 years averaged 3.0 and 5.4 percent, respectively. Foreign material (FM) averaged about 5 percent. If FM and SS percentages exceed 4 percent, the support price is reduced. The value of peanut lots depends on other grade factors, such as sound mature kernels (SMK), other kernels (OK), extra large kernels (ELK), fancy size, and moisture content (MC).

Table 3. Grade data for farmers stock peanuts harvested conventionally in Virginia.[1]

Factors	1971	1972	1973	1974	1975	1976	Average
			Percent				
SMK	67.7	63.0	66.6	63.4	66.5	65.6	65.5
SS	3.5	3.1	2.2	2.7	2.8	3.6	3.0
OK	2.4	3.8	2.6	3.7	3.1	3.3	3.2
Damage	1.0	1.4	0.7	1.0	0.5	0.9	0.9
Hulls	25.4	28.7	27.9	28.3	27.1	26.6	27.3
FM	5.1	5.4	4.7	4.9	4.1	4.6	4.8
LSK	7.8	6.0	4.7	4.5	4.3	5.0	5.4
MC	8.7	8.5	7.4	8.0	8.6	8.8	8.3
Fancy	74.6	73.4	75.8	68.5	78.3	70.6	73.5
ELK	29.8	27.2	30.3	22.6	29.9	36.0	29.3

1 Source: Peanut Marketing in Virginia. Va. Dept. of Agric. and Commerce, Market News Service, Windsor, Va. 1976.

Direct harvesting system. The primary objective of research on direct harvesting has been to reduce peanut damage and the potential for mold contamination. The direct harvester developed at Suffolk, Va., uses a picking principle that depends on the natural orientation of the peanut plant (1, 10) and effectively eliminates mechanical damage during harvest.

The direct harvester consists of digging, picking, and cleaning sections. In one pass through the field, the experimental machine lifts the plant from the soil, separates the peanuts from the plant, returns the plant material to the soil surface, separates extraneous foreign material from the peanuts, and places the peanuts in a container. Peanuts are removed with less energy than that used with the conventional method, and potential losses in the windrow due to adverse weather are eliminated.

The digger components cut the vines between the plant rows, slice the soil under the plant, lift the plants from the soil, and elevate them in a manner similar to a conventional digger. The plants are moved into the picking section in a manner which maintains the natural plant orientation.

The picking section consists of three rotating drums, an overhead conveyor, a vibrating rack, and a rod-chain conveyor. The first and third drums rotate against the flow of plants, and the second drum rotates with the flow of plants. Attached to the 30.5-cm (12-in.)

diameter drums are nine notched strips 4.4 cm (1.75 in.) high. As the plants are moved over the vibrating rack by the overhead conveyor, the peanuts hang below the rods of the vibrating rack and are removed by the notched strips on the rotating drums. The peripheral velocity of each of the drums is about 3.0 m/s (600 fpm) relative to the plant movement through the picking section. The peanuts fall onto the rod-chain conveyor and are moved into the cleaning section. The spaces between the rods of the chain conveyor allow some excess soil and small immatures or undeveloped peanuts to pass through.

The cleaning components include a paddle section to remove long plant branches, a suction fan to remove leaflets and fine roots, and a stemming saw section to remove pegs from the pods. At the present stage of development the peanuts are placed in bag containers rather than in bulk bins.

The field performance of the direct harvester over 3 years is summarized in Table 4 for harvests of the VA 61R cultivar. The results obtained with the Florigiant cultivar were equal to or better than those presented for the VA 61R cultivar.

Table 4. Summary data for direct harvesting of VA 61R cultivar peanuts.

Factors	Year/Diggings 1971/3	1972/3	1973/6	1974/4	1975/2	Average
		Percent				
Picking Efficiency[1]	95	95	98	98	96	96
Damaged Pods (visible)	3	8	5	3	4	5
LSK	0	0	0	0	0	0
Shelling Damage	1.0	0.8	0.5	1.7	1.0	1.0
Germination	98	95(84)[2]	95	95(83)[2]	96(93)[2]	96(91)[2]
Foreign Material	6	9	4	8	4	6
Peanut MC	56	65	54	65	53	59

1 Ratio of peanuts removed to the total peanuts passing through the machine, expressed as a percent based on weight.

2 Includes low readings not attributed to machine operation.

The machine was effective in removing 96 percent of the peanuts (by weight) from the plants passing through the picking section. The visible pod damage averaged less than 5 percent, LSK was nil, and subsequent shelling damage averaged 1 percent.

Germination values averaged 96 percent. As noted in Table 4, low germination values in 1972, 1974, and 1975 were attributed to factors other than damage by machine components. For example, the low values occurred when ambient temperatures were low during the drying period. This aspect deserves further study.

FM ranged between 4 and 9 percent. The FM values rise when the peanuts are harvested at premature stages. This low level of maturity (as indicated by a high peanut moisture content at harvest) is the result of late maturity or an early killing frost. Grade data for the direct harvester are presented in Table 5.

Table 5. Grade data for direct harvesting of VA 61R peanuts in Virginia.[1]

Factors	1971	1972	1973	1974	1975	Average
			Percent			
SMK	68.5	48.9	68.3	63.6	69.8	63.8
SS	1.0	0.8	0.5	1.7	1.0	1.0
OK	3.2	6.7	2.2	4.6	1.8	3.7
Damage	0.5	4.2	1.1	0.2	0.6	1.3
Hulls	26.7	39.4	27.8	29.8	26.8	30.1
FM	5.8	9.0	4.1	6.7	3.6	5.8
LSK	0	0	0	0	0	0
MC	6.0	7.4	7.8	6.4	7.3	7.0
Fancy	68.8	73.7	78.6	56.0	80.6	71.5
ELK	24.5	19.7	31.1	11.3	27.8	22.9

1 Average for two to six digging dates, depending on year.

The cleaning components performed satisfactorily in removing long plant branches and extraneous FM. The percent of peanuts harvested with the peg still attached ranged from 10 to 40 percent, or inversely with peanut maturity. The stemming saw section effectively removed about 50 percent of these pegs. Although insignificant relative to large amounts of FM, the peg left on the peanut can cause obstruction during handling operations.

Peanuts freshly dug and removed from the plant have more soil adhering to the pods than peanuts harvested from the windrow, especially with Florigiant cultivar. The amount of soil adhering to the pods depends on the soil type, soil moisture, and peanut cultivar. No attempt was made to measure this factor.

Before the soil is sliced and lifted, the vine mass is cut with coulters to a width of about 74 cm (29 in.). The peanuts are removed, and the vine mass is left intact. The vine mass is in excellent condition to be used for peanut hay or chopped into silage. The nutrient value of peanut hay is equal to that of alfalfa hay. Peanut hay yields are about 4500 kg/ha (2 tons/acre). In addition to removing the vines for feed, they can also be removed to prevent the incidence of plant diseases. Thus, the removal of vines serves a two-fold purpose.

Presently, application of some pesticides on peanuts restricts the use of vines for feed uses. This restriction is the result of insufficient data and a request for clearance rather than harmful effects of residual chemicals. The potential use of peanut vines for feed uses should be determined.

Peanut Curing and Drying Operations

Artificial drying is necessary for conventional and direct-harvested peanuts because the peanut moisture content is too high at harvest for safe storage. To be accepted at the market and safe for storage, the peanut moisture content must be 10 percent or less. Drying peanuts is often considered as simply moisture removal, but proper curing requires a process of controlled moisture removal (5). Proper curing requires a few days, and the rate of drying is the key to maintaining the quality of the harvested peanut. Excessive skin slippage, excessive splits, and "off" flavor are good indicators of drying too rapidly or at excessive temperatures.

In conventional harvesting, peanuts are left in an inverted windrow to dry. The moisture content decreases to 25 to 35 percent after 4 to 7 days of windrow exposure (Fig. 1). Peanut damage is minimal when combining is done within this moisture-content range. In the Virginia area, the peanut moisture content seldom goes lower than 20 percent when left in an inverted windrow for 10 to 12 days.

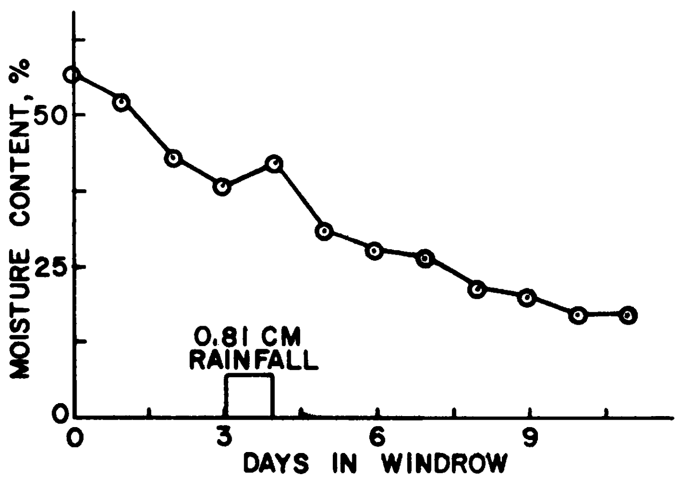

Fig. 1. Peanut moisture content during exposure in inverted indrow.

The moisture content of freshly dug peanuts of the VA 61R cultivar ranges between 50 and 60 percent. The moisture content of the Florigiant cultivar ranges between 45 and 55 percent for a normally mature crop of peanuts. In direct harvesting the peanuts are removed from the plant at this high moisture-content level. The basic difference in the drying and curing requirements of the two systems is the moisture-content level of the peanut when artificial drying is initiated.

The recommended drying procedures for conventionally harvested peanuts are the same whether the peanuts are bin-dried or trailer-dried. Fan systems should provide a minimum airflow of 0.254 $m^3/s/m^2$ (50 cfm/ft^2) of floor area, or 0.25 $m^3/s/m^3$ (15 cfm/ft^3) of peanuts in the dryer. Most commercial systems meet these requirements and will operate satisfactorily with peanut depths of 1.2 to 1.5 m (4 to 5 ft). The temperature of the drying air should not exceed 35°C (95°F), and heat should not be added to the drying air if it lowers the humidity below 50 to 55 percent. If a humidity control is not used or is not functioning properly, the LP gas pressure should be adjusted to raise the temperature of the drying air not more than 8.3°C (15°F) above ambient while retaining the upper limit of 35°C (95°) for the temperature of the heated air. The dryers should be turned off or the peanuts can be removed when the average moisture content reaches 10 percent. Management of the drying equipment and controls is very important if peanut quality factors, such as high germination, good flavor, and minimum skin slippage, are to be retained.

No special equipment is available for drying peanuts harvested by the direct method, but conventional drying equipment can be used with slight modification in procedures. Ambient air should be passed through the peanuts for 24 to 48 hrs before heat is added. The depth of high-moisture peanuts in drying bins or trailers shold be reduced to about two-thirds the depth normally used in conventional drying. Otherwise,the drying equipment and controls can be managed with the same procedures used for conventionally harvested peanuts.

Drying direct-harvested peanuts has several advantages. The moisture removal is completely controlled by the drying equipment operator, and the potential for contamination by molds in the windrow is eliminated. Excellent seed germination and flavor can be preserved. In the initial stages of drying, the bottom layer of peanuts first exposed to the drying air is most susceptible to loss in flavor and seed quality. Passing ambient air through the peanuts for the first 24 to 48 hrs can reduce these losses. If the entering air temperature exceeds 32.2°C (90°F) or the drying potential exceeds 3.3 to 4.4°C (6 to 8°F) wet-bulb depression during this period, flavor and seed quality are reduced in the first 0.3 to 0.6 meters (1 to 2 ft) of peanuts.

A major factor preventing the peanut producer from adopting the direct-harvesting method is the costs associated with drying high-moisture peanuts. For example, to yield peanuts at 8 percent moisture content, peanuts with 55 percent moisture content must have 2.5 and 4.5 times more water removed from them than those with 35 percent and 25 percent, respectively. These ratios suggest that drying time, fan energy, and fuel costs increase by a similar ratio. Although variable costs contribute heavily, the results presented below show that fixed costs contribute more than any other factor to the increase in cost of drying high-moisture peanuts.

In a laboratory drying study, peanuts were harvested conventionally at about 30 percent moisture content and were placed 1.2 m (4 ft) deep in a controlled drying environment. The drying air was maintained at a dry-bulb temperature of 23.3°C (74°F) and wet-bulb temperature of 15.6°F). Airflow and air temperatures were recorded periodically. Airflow through the peanuts averaged 0.028 m^3/s (60 cfm) or 0.25 $m^3/s/m^3$ (15 cfm/ft^3) of peanuts.

Under these conditions, the temperature of drying

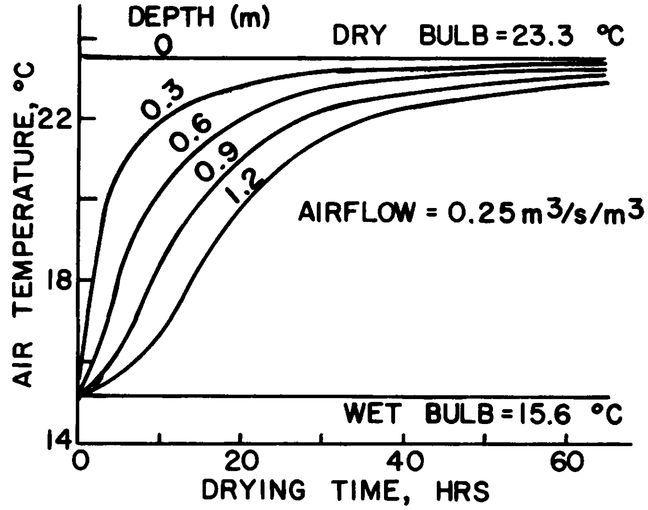

Fig. 2. Air temperatures with time at selected depths in a fixed-bed, controlled-temperature peanut drier as peanuts dried from a moisture content of 30% to 8.2%.

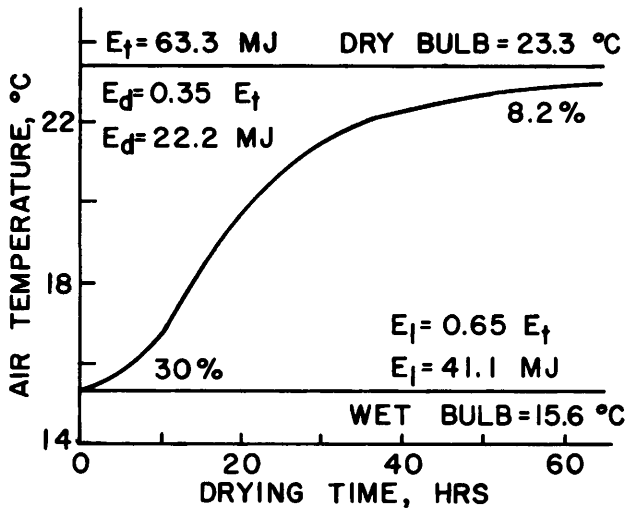

Fig. 3. Graphic representation of total energy input with time for fixed-bed drying of conventionally harvested peanuts from 30% moisture content to 8.2%.

air indicated the amount of moisture that was removed from the peanuts (Fig. 2). About 65 hrs were required to dry the peanuts from 30 percent to 8.2 percent moisture content. In this figure the total thermal energy input (E_t) available for moisture removal can be estimated by $E_t = Kt(\Delta T)$ where K is a constant of the drying environment, t is time of drying, ΔT is difference between dry-bulb and wet-bulb temperatures (wet-bulb depression). This expression requires constant airflow rate and wet-bulb depression during the drying period. An adiabatic process is assumed, and the heat content of the water vapor is neglected. This expression is represented graphically in Fig. 3 by the rectangular area, t x ΔT. This area is divided by the curved line representing the temperature of exhaust air at the 1.2-meter (4-ft) level. The energy to remove moisture (E_d) is represented by the area above the curved line and the energy exhausted (E_l) is represented by the area below the curved line. For the case described, about 63.3 MJ (60,000 BTU) were supplied to dry the peanuts. Because only 22.2 MJ (21,000 BTU) of energy were used to remove moisture, the fixed-bed thermal efficiency (E_d/E_t) was 35 percent.

Peanuts harvested by the direct method and placed in the same drying environment required about twice as much time as peanuts from conventional harvesting to reduce the moisture content from 55 percent to 8.2 percent (Fig. 4). Because of the high peanut moisture content, the fixed-bed thermal efficiency increased to 67 percent.

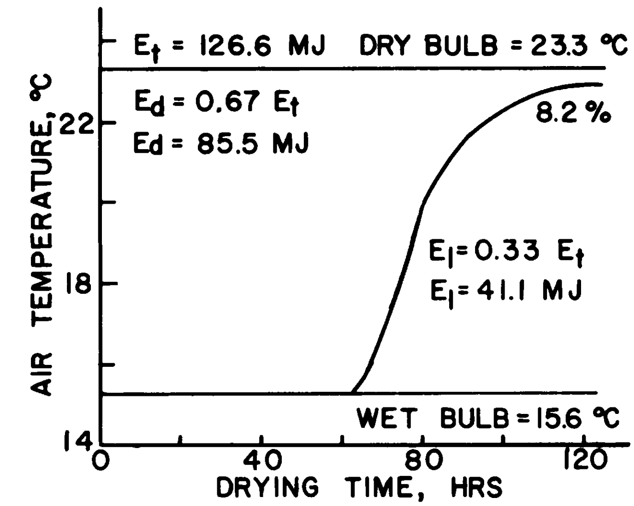

Fig. 4. Graphic representation of total energy input with time for fixed-bed drying of direct harvested peanuts from 55% moisture content to 8.2%.

Table 6. Fuel cost to dry peanuts at two initial moisture contents and yield 45.4 kg (100 lbs) at 8% moisture content.[1]

Moisture Content - %	30	55	55
Initial Weight - lbs	132	205	205
Thermal Efficiency - %	35	67	100
Total Thermal Energy - MJ	113.9	198.4	132.9
From LP Gas - MJ	76.0	132.9	88.6
Fuel Cost - $	0.32	0.56	0.37

1 Note: Based on a heat of combustion for LP gas of 25 MJ/liter and two-thirds of the total energy provided by LP gas combustion at 10.6¢/liter. Thermal efficiency of 100% assumed for comparisons only.

Table 6 shows the fuel cost to dry peanuts at two initial moisture contents and yield 45.4 kg (100 lb) at 8 percent moisture content. The fuel costs to dry peanuts with 30 percent moisture content is calculated at $0.32, as compared to $0.56 for peanuts at 55 percent moisture content. If the assumption is made that equipment and drying procedures could by improved to achieve 100 percent thermal efficiency, the drying fuel cost would be $0.37 for peanuts at 55 percent moisture content. The cost of drying direct-harvested peanuts with experimental fixed-bed thermal efficiencies, drying time, and estimated fixed operation expenses equals about twice the cost of drying conventionally harvested peanuts (Table 7). The fixed costs account for over 50 percent of the additional expenses.

Table 7. Total cost of drying conventionally and direct-harvested peanuts to yield 45.4 kg (100 lbs) at 8% moisture content.

Cost	Conventional 35%[1]	Direct 67%[1]	Direct 100%[1]
	(Dollars)		
Fan[2]	0.07	0.13	0.09
Fuel	0.32	0.56	0.37
Fixed[2]	0.43	0.98	0.98
Total	0.82	1.67	1.44

1 Thermal efficiency.

2 Fan and fixed costs were increased 25% above those presented in reference 4.

Conclusions

The direct harvesting of peanuts eliminates the potential for losses in the windrow from adverse weather. With this method, visibly damaged pods can be reduced 80 percent, subsequent shelling damage can be reduced 65 percent, and germination percentages of 98 percent can be obtained. The greatest disadvantage is the higher drying costs, because artificial drying of the peanuts is started at about 55 percent with the direct method, as compared to about 30 percent moisture content with conventional harvesting.

The fixed-bed thermal efficiency of drying peanuts at 55 percent moisture content was 67 percent, compared to 35 percent for peanuts at 30 percent moisture content. The total drying cost for high-moisture peanuts was about twice that for partially dried peanuts. About 50 percent of the increase in cost was due to additional expenses for fixed-cost items.

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