190

Paper No. 936545
An ASAE Meeting Presentation

EFFECT OF DRYING AND STORAGE ON INDIVIDUAL PEANUT KERNEL MOISTURE CONTENTS

by

Floyd E. Dowell, Christopher L. Butts and John S. Smith, Jr.
Agricultural Engineers
USDA, ARS, National Peanut Research Laboratory
Dawson, Georgia 31742

Written for Presentation at the
1993 ASAE International Winter Meeting
Sponsored by
ASAE

Chicago, Illinois
14-17 December 1993

Summary:

Single peanut kernel moistures vary widely around the mean. These high moisture single kernels may contribute to aflatoxin in storage. This study showed single kernel moistures at farmer marketing can be 2 to 3 times the average moisture. Mechanical, or forced air, drying reduced average moistures while narrowing the range of single kernel moistures. However, forced air drying initially raised moisture levels in the top portion of the peanut mass in some trailers. The middle and bottom portions of the trailer dry more quickly and to a moisture level lower than the top of the trailer. In storage, some samples with average MC greater than 13.5% were contaminated with mold and aflatoxin. Samples with average MC less than 13.5% but with a few high moisture kernels did not have mold or aflatoxin problems.

Keywords:

Peanuts, grading, moisture content, aflatoxin, drying, storage, warehousing

INTRODUCTION

Physiological maturity and environmental conditions in the windrow, during mechanical drying, or during storage affect peanut kernel moisture contents (MC). Peanuts are indeterminate, and thus kernel maturity at harvest varies from immature to mature. Kernels may vary from about 15% to 90% MC (wet basis) where the mature kernels are usually lower in MC than immature (Dorner *et al.*, 1989). Improper drying or storage conditions cause variations in kernel moisture if non-uniform drying or rewetting of the peanuts occur (Smith *et al.*, 1989). Regardless of the source of moisture, if peanuts are not dried properly, or are rewetted, *Aspergillus flavus* and the subsequent formation of aflatoxin may occur. One key to maintaining quality is to insure moisture is reduced and maintained at safe levels without allowing *A. flavus* to form. The temperature and relative humidities influencing *A. flavus* and aflatoxin formation are well known (Austwick and Ayerst, 1963; Diener and Davis, 1969; Diener and Davis, 1977; Welty and Cooper, 1968). However, individual kernel moisture ranges during drying and storage are not known. The objective of this research was to measure the variations in single kernel moisture contents and determine how these individual kernels dry during mechanical drying and storage.

The main factors influencing the growth of fungi in peanut pods and seed are moisture (relative humidity), temperature, and time (Diener, 1973). High mycofloral counts are associated more often with high initial moistures of peanuts going into storage than any other factor (Diener, 1960). Storage fungi are more active in the mycoflora of peanut seed during curing and storage when the seed MC is above 8-10%, or about 85% relative humidity; below this level, they become inactive. Increases in moisture from rewetting in storage or exposure to high humidity for extended periods of time will result in rapid buildup of mycofloral fungi including *A. flavus* (Jackson and Press, 1967; Welty and Cooper, 1968; Diener and Davis, 1967, 1968, 1970; Austwick and Ayerst, 1963; Smith *et al.*, 1989). When drying of the peanut lowers the seed MC rapidly and steadily downward within 4 or 5 days to safe storage moisture, little opportunity for fungal invasion occurs (McDonald and Harkness, 1963). Peanuts were most rapidly invaded by *A. flavus* during drying or dehydration in windrows at 14 to 30% MC (McDonald and Harkness, 1964; McDonald *et al.*, 1964; Dickens and Pattee, 1966; Pettit *et al.*, 1971). Apparently, *A. flavus* does not become established rapidly in peanuts at higher or lower moisture contents (Austwick and Ayerst, 1963; McDonald and Harkness, 1964, 1965; Porter *et al.*, 1972). Artificial drying after 4 to 6 days in the windrow gave toxin-free seed, but peanuts left for 8 to 12 days or sun-dried for 10 to 16 days contained from 25 to 500 ppb aflatoxin (McDonald and A'Brook, 1963). The longer the crop was in the field before artificial drying, the higher the aflatoxin content (McDonald and A'Brook, 1963; Jackson, 1967). Temperature and relative humidities in locations within the warehouse can increase due to excess heat, moisture, heat of respiration, and microbial activity in the peanuts (Smith *et al.*, 1985; Sanders *et al.*, 1981), thus increasing susceptibility to aflatoxin.

Thus, the conditions conducive to *A. flavus* growth and aflatoxin production are well defined. However, all previous research is based on average kernel moistures. Little is known about the ranges of kernel moistures present during drying and storage. Thus, even though average kernel moisture may appear acceptable, this average may consist of some high moisture kernels. This paper reports the average and single kernel moisture measured during curing and storage. This knowledge can be used to develop grading procedures to detect ranges of moistures in incoming farmers stock peanuts so actions, such as further drying or segregation, can be taken to minimize aflatoxin in edible peanuts.

PROCEDURES

A single kernel moisture meter tested in previous research (Dowell and Lamb, 1991) measured and recorded individual kernel moisture in 3 different tests. Test #1 consisted of measuring single kernel moistures in 500 g grade samples from 522 trailers to define the existing ranges of moistures in farmers stock peanuts. Approximately 160 kernels from each sample were measured. Test #2 defined the drying front in mechanically dried peanuts to determine what variations in kernel moistures may be caused by forced air drying. One hundred sixty kernels from 500 g samples from the top, middle, and bottom layers of 7 trailers were analyzed at approximately 4 hour intervals during drying. This test also showed how average and maximum moistures change over time. Storage effects on single kernel moisture were studied in test #3. During this test, six 500 g samples in the following moisture ranges were stored: 5-10%, 11-15%, 16-20%, and 21-25%. Single kernel moistures and aflatoxin levels were measured on a 160 kernel subsample removed from the sample before and after storage. The 500 g sample was placed in a small mesh bag which was then placed in a large mesh bag containing about 18 kg of peanuts. The bag containing the sample was buried 1/3 to 3 meters below the surface of the peanut mass in the warehouse. The average moisture of the peanut mass was less than 10.5% and likely close to 7%. Peanuts were placed in a conventional, mechanically ventilated warehouse on October 13, 1992 and removed on December 1, 1992. Aflatoxin was measured using the Vicam aflatoxin test and positive readings confirmed with high performance liquid chromatography.

RESULTS

Figure 1 shows average MC and the 95% confidence interval (CI) for 522 trailers of farmer marketed peanuts. The average MC of all samples was 11.71% and the average standard deviation was 2.2%. As expected, the standard deviation (SD) increased with the average MC. The CI in Figure 1 shows that when peanuts are marketed at about 10.5% MC, some lots may have kernels with moistures around 14%. If these lots are stored in conditions that don't allow further drying, *A. flavus* is likely to grow on the higher moisture kernels. If peanuts are harvested around 20% MC and placed in trailers, then some of the kernels could be in the 25-30% MC range. Thus, proper drying of peanuts on wagons or in storage is critical.

Figure 2 shows the average MC of the top, middle, and bottom of a typical trailer of farmers stock peanuts during drying. Notice, for this trailer, the top layer actually gains moisture initially as the lower layers lose moisture. Moisture removed from the lower layers saturate the air, which rewets the upper layers. There is a 1 to 3% moisture differential between the layers throughout the drying process. The differential from top to bottom was approximately 2% at completion of drying. In general, the layer-to-layer variations in moisture content, as reflected in the average, increased from the beginning of mechanical drying until drying was completed. However, kernel-to-kernel differential, as reflected in the SD, decreased (Table 1). Thus, even though forced air drying removes moisture, it may actually contribute to variations in average moistures in different layers in the trailer. The only way to eliminate this effect would be to change the drying process such that all kernels were exposed to the same drying air conditions.

Figure 3 shows how average and single kernel moisture, as reflected by the CI, decreases during drying. The difference between the average moisture line and CI line decreases with time indicating that the higher moisture kernels lose moisture faster than other kernels. Thus, additional drying time is effective in reducing the variation in kernel moisture. Table 1 shows the average and SD for all trailers.

Table 2 shows the average and maximum kernel moisture and SD of kernel moistures for kernels before and after storage. Average and maximum kernel moistures ranged from about 5 to 30% before storage. However, all average moistures dried to about 8% by the end of the storage period. Post-storage maximum single kernel moistures ranged from 8.5 to about 13%. Three of 24 post-storage samples with initial average moistures above 13.5% were contaminated with aflatoxin at levels of 8, 15, and 250 ppb. In addition, 10 of those samples contained molds other than *A. flavus*. Thus, aflatoxin was produced and molds formed during storage in samples with high initial average moistures. No aflatoxin or molds were observed in samples containing high MC single kernels where average MC was less than 13.5%. Thus, these few high MC kernels must readily lose moisture during storage, thus preventing *A. flavus* and aflatoxin formation.

In conclusion, this study showed single kernel moistures at farmer marketing can be 2 to 3 times the average moisture. Mechanical, or forced air, drying reduced average moistures while narrowing the range of single kernel moistures. However, forced air drying may initially raise moisture levels in the top portion of the peanuts. The middle and bottom portions of the trailer dry more quickly and to a moisture level lower than the top of the trailer. In storage, samples with average MC greater than 13.5% were more likely to mold and have aflatoxin than samples with lower average moistures. Samples with average MC less than 13.5% but with a few high moisture kernels did not have mold or aflatoxin problems.

Future work will focus on examining the feasibility of implementing single kernel moisture measurement into the farmers stock grading process. Sample size, economics and integration into the present grading process are among the issues that need to be addressed before implementation.

ACKNOWLEDGMENTS

The authors thank Hank Sheppard, Larry Dettore, Larry Powell, Manuel Hall, and Sandra Bowens for their technical support.

REFERENCES

Austwick, P.K.C. and G. Ayerst. 1963. Toxic products in groundnut: Groundnut microflora and toxicity. *Chem. In. (London)* 2:55-61.

Dickens, J. W. and H. E. Pattee. 1966. The effects of time, temperature, and moisture on aflatoxin production in peanuts inoculated with a toxic strain of *Aspergillus flavus*. *Trop. Sci.* 8:11-22.

Diener, U. L. 1960. The mycoflora of peanuts in storage. *Phytopathology* 50:220-223.

Diener, U. L. 1973. Deterioration of peanut quality caused by fungi. *In Peanuts: Culture and Uses*, 523-557. Stillwater, OK:Am. Peanut Res. Educ. Soc.

Diener, U. l. and N. D. Davis. 1967. Limiting temperature and relative humidity for growth and production of aflatoxin and free fatty acids by *Aspergillus flavus* in sterile peanuts. *J. Am. Oil Chem. Soc.* 44:239-263.

Diener, U. L. and N. D. Davis. 1968. Effect of environment on aflatoxin production in freshly dug peanuts. *Trop. Sci.* 10:22-28.

Diener, U. L. and N. D. Davis. 1969. Aflatoxin formation by *Aspergillus flavus*. *In Aflatoxin*, 13-54, L. A. Goldblatt (ed.). New York:Academic Press, Inc.

Diener, U. L and N. D. Davis. 1970. Limiting temperature and relative humidity for aflatoxin production by *Aspergillus flavus* in stored peanuts. *J. Am. Oil Chem. Soc.* 47:347-351.

Diener, U. L. and N. D. Davis. 1977. Aflatoxin formation in peanuts by *Aspergillus flavus*. Auburn University Agric. Exp. Stn. Bull. 493, 49 pp.

Dorner, J. W., R. J. Cole, T. H. Sanders, and P. D. Blankenship. 1989. Interrelationship of kernel water activity, soil temperature, maturity, and phytoalexin production in preharvest aflatoxin contamination of drought-stressed peanuts. *Mycopathologia* 105:117-128.

Dowell, F. E. and M. C. Lamb. 1991. Accuracy and feasibility of determining single peanut kernel moisture content. *Peanut Sci.* 18:131-136.

Jackson, C. R. 1967. Some effects of harvesting methods and drying conditions on development of aflatoxins in peanut. *Phytopathology* 57:1270-1271.

Jackson, C. R. and A. F. Press, Jr. 1967. Changes in mycoflora of peanuts. *Oleagineux* 22:165-168.

McDonald, D. and J. A'Brook. 1963. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. III. *Trop. Sci.* 5:208-214.

McDonald D. and C. Harkness. 1963. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. II. *Trop. Sci.* 5:143-154.

McDonald, D. and C. Harkness. 1964. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. IV. *Trop. Sci.* 6:12-27.

McDonald, D. and C. Harkness. 1965. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. VIII. *Trop. Sci.* 7:122-137.

McDonald, D., C. Harkness and W. C. Stonebridge. 1964. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. VI. *Trop. Sci.* 6:131-154.

Pettit, R. E., R. A. Taber, H. W. Schroeder and A. L. Harrison. 1971 Influence of fungicides and irrigation practices on aflatoxin in peanuts before digging. *Appl. Microbiol.* 22:629-634.

Porter, D. M., F. S. Wright and J. L. Steele. 1972. Relationship of shell damage to colonization of peanut seed by *Aspergillus flavus*. *J. Am. Peanut Res. Educ. Assoc.* 4:207. Abstr.

Sanders, T. H., J. S. Smith, Jr., J. A. Lansden, and J. I. Davidson. 1981. Peanut quality changes associated with deficient warehouse storage. *Peanut Sci.* 8:121-124.

Smith, J. S., Jr, T. H. Sanders, and K. L. Crippen. 1989. Storability of farmers stock peanuts at two moisture levels in mechanically and naturally ventilated miniature warehouses. *Peanut Sci.* 16:58-62.

Smith, J. S., Jr., J. I Davidson, Jr., T. H. Sanders, and R. J. Cole. 1985. Storage environment in a mechanically ventilated peanut warehouse. *Tranactions of the ASAE* 28(4):1248-1252.

Welty, R. E. and W. E. Cooper. 1968. Prevalence and development of storage fungi in peanut *Arachis hypogaea* seed. *Mycopathol. Mycol. Appl.* 35:290-296.

Table 1. Average and standard deviations of single kernel moisture contents in the top, middle, and bottom of trailers of farmers stock peanuts during drying.

		Top Layer		Middle Layer		Bottom Layer		All Layers	
Trailer	Time (hrs)	Avg. (%)	Std. Dev. (%)	Avg. (%)	Std. Dev. (%)	Avg. (%)	Std. Dev. (%)	Avg. (%)	Std. Dev. (%)
1	0	14.5	2.1	12.8	1.4	14.9	2.1	14.1	1.9
	4	10.8	1.2	*	*	11.1	1.3	11.0	1.2
	7	11.7	1.6	10.3	1.7	8.8	1.2	10.3	1.5
	10	10.9	1.8	9.5	1.1	9.1	1.4	9.8	1.4
2	0	*	*	13.2	2.9	*	*	13.2	2.9
	6	14.2	3.3	*	*	12.7	2.9	13.5	3.1
	10	11.7	1.9	11.7	1.9	10.8	1.8	11.4	1.9
	13	10.6	1.9	9.8	2.4	9.6	2.3	10.0	2.2
3	0	21.7	4.1	23.1	3.9	22.8	3.1	22.5	3.7
	6	22.8	3.3	20.3	4.3	19.3	3.8	22.8	3.8
	10	21.5	4.1	18.5	3.1	18.9	3.7	19.6	3.6
	14	15.3	2.4	12.8	1.8	11.7	1.4	13.3	1.9
	19	13.7	3.0	11.2	1.5	9.6	1.4	11.5	2.0
	23	11.2	1.7	8.9	1.2	8.7	1.4	9.6	1.4
	27	10.2	1.8	9.4	1.4	9.3	2.1	9.6	1.8
4	0	*	*	19.2	2.3	18.4	2.8	18.7	2.5
	4	*	*	16.3	2.2	13.8	1.5	15.1	1.8
	8	15.2	2.1	11.6	1.2	9.8	0.9	12.2	1.4
5	0	18.9	2.4	14.7	1.6	18.6	2.5	17.4	2.2
	4	*	*	18.1	2.2	13.1	1.1	15.6	1.7
	8	13.0	1.8	*	*	*	*	13.0	1.8
	12	*	*	*	*	10.3	1.3	10.3	1.3
6	0	16.1	2.1	16.1	1.8	16.6	2.4	16.2	2.1
	4	12.8	1.2	12.2	1.1	12.3	1.2	12.4	1.2
	8	11.9	1.1	10.6	1.5	9.1	0.9	10.6	1.2
	12	11.7	1.0	9.1	1.0	10.2	1.7	10.3	1.2
7	0	14.8	1.6	14.5	1.2	13.4	1.0	14.3	1.3
	4	*	*	11.8	0.9	9.8	0.9	10.8	0.9
	8	10.7	4.0	10.5	0.7	9.5	0.7	10.2	1.8
	12	9.9	0.8	9.4	0.7	9.0	0.8	9.4	0.8

* Samples deleted due to delays in measuring moistures.

Table 2. Average, maximum, and standard deviations of single kernel moisture contents in samples of peanuts before and after storage. The storage period began on October 13 and ended December 1, 1992.

Sample	Before Storage			After Storage		
	Avg. (%)	Max. (%)	Std. Dev. (%)	Avg. (%)	Max. (%)	Std. Dev. (%)
1	5.3	9.4	3.8	8.1	13.2	1.9
2	7.4	20.8	1.8	8.1	10.9	1.8
3	7.5	15.7	2.2	7.8	10.4	1.3
4	7.6	11.5	0.9	7.3	10.9	1.3
5	9.1	30.5	3.6	7.5	10.4	1.2
6	9.7	12.0	1.1	8.0	9.9	0.6
7	10.7	21.5	2.9	8.2	10.4	0.9
8	12.5	25.1	2.0	7.4	9.0	0.7
9	13.0	25.6	4.2	8.4	10.9	0.8
10	13.7	22.6	5.2	8.7	11.5	0.8
11	14.2	28.7	5.1	8.0	11.5	1.0
12	14.7	26.1	2.4	7.8	9.9	0.8
13	16.4	30.3	6.9	8.0	12.0	1.4
14	16.6	26.6	3.1	7.7	11.5	1.4
15	16.9	30.5	5.0	8.3	12.0	1.4
16	17.8	27.5	4.7	8.2	11.5	1.3
17	18.3	23.6	5.3	8.2	10.4	1.3
18	19.0	30.4	6.8	7.9	10.4	1.3
19	20.0	28.4	3.5	7.9	10.9	0.9
20	21.1	29.7	4.0	7.5	10.9	0.9
21	22.2	30.5	6.9	8.4	12.6	1.1
22	24.0	30.4	4.9	7.3	8.5	0.6
23	24.4	30.3	4.6	8.0	11.5	1.2
24	25.9	30.5	4.5	8.1	12.0	1.2

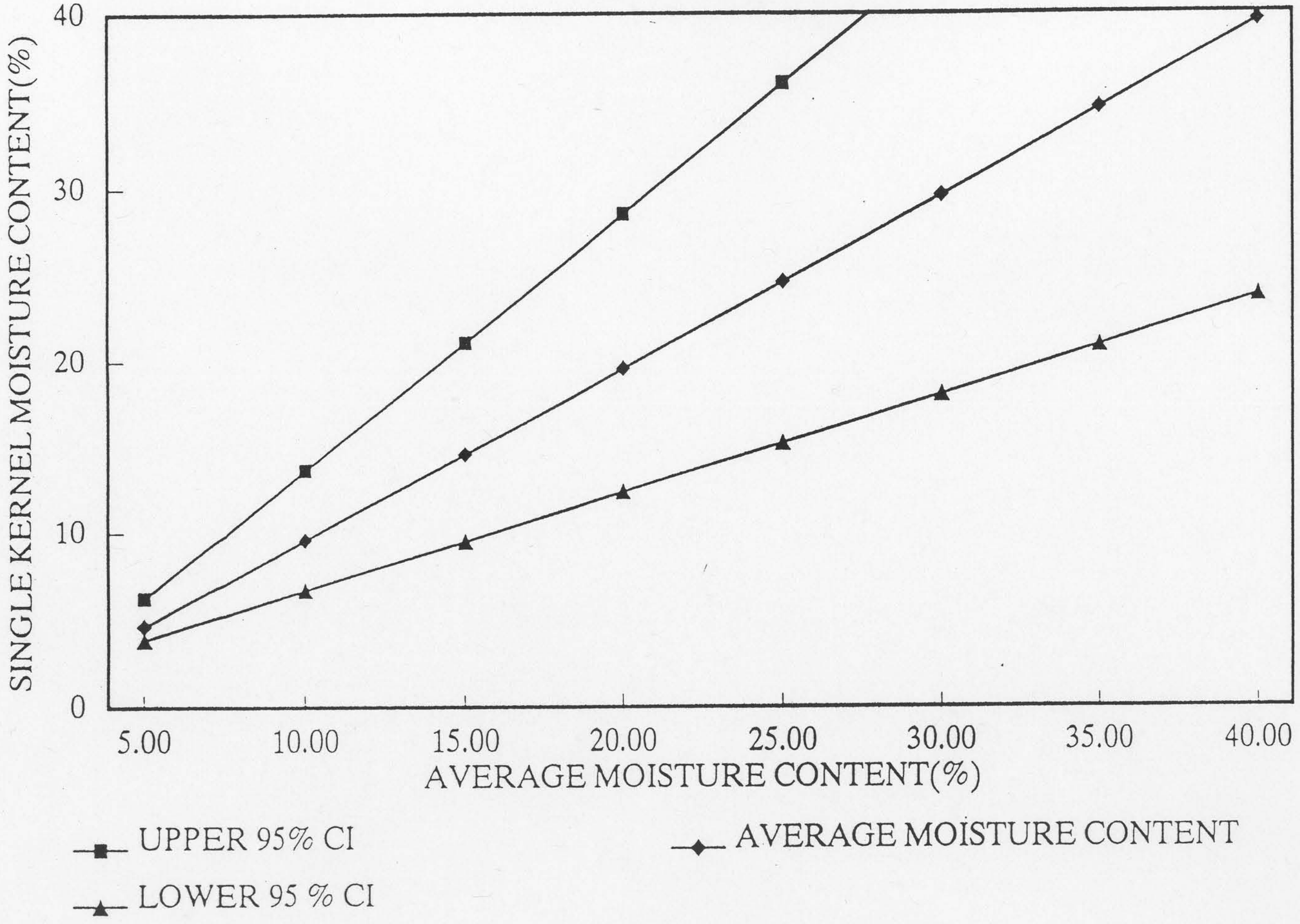
FIGURE LEGENDS

Figure 1. Average and 95% confidence interval (CI) of single kernel moistures from 522 trailers of farmers stock peanuts.

Figure 2. Average moisture content in the top, middle, and bottom layer of a trailer of farmers stock peanuts during drying.

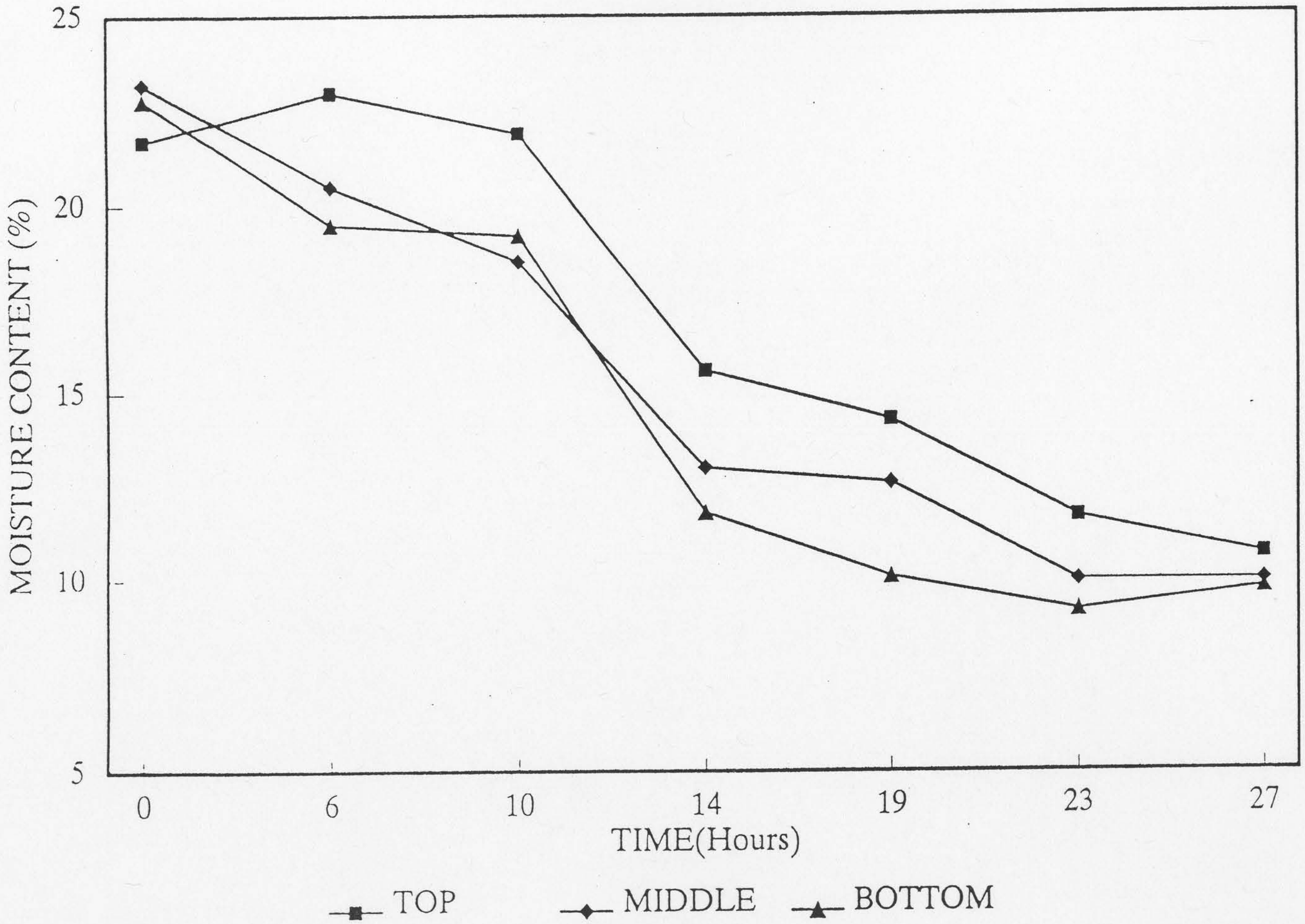
Figure 3. Average and 95% confidence interval (CI) of single kernel moistures of farmers stock peanuts during forced air drying in a trailer.

FIGURE 1



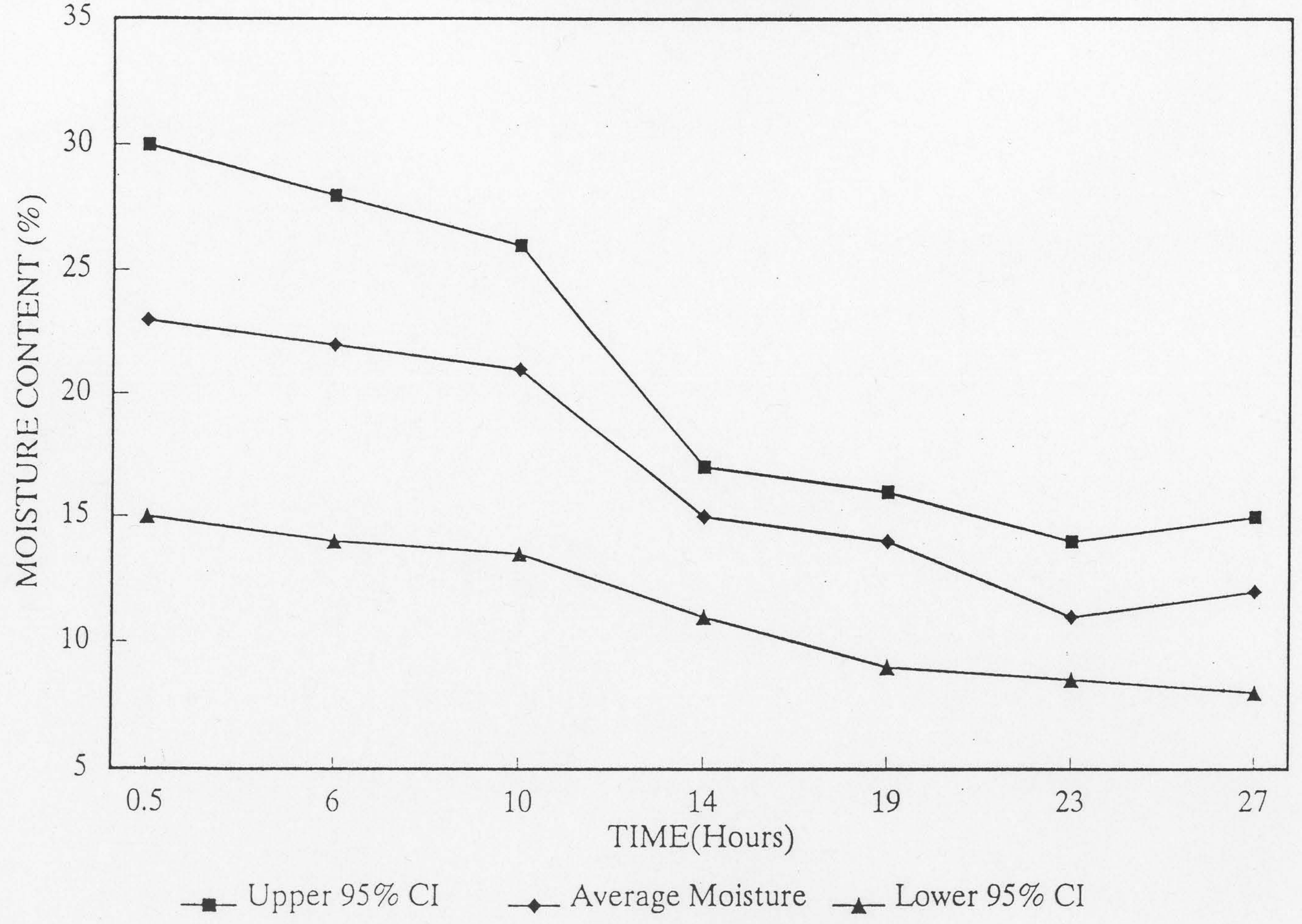
SINGLE KERNEL MOISTURE CONTENT(%)
40
30
20
10
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
AVERAGE MOISTURE CONTENT(%)
UPPER 95% CI
AVERAGE MOISTURE CONTENT
LOWER 95 % CI

FIGURE 2



MOISTURE CONTENT (%)
25
20
15
10
5
0
6
10
14
19
23
27
TIME(Hours)
TOP
MIDDLE
BOTTOM

FIGURE 3


35
30
25
20
15
10
5
MOISTURE CONTENT (%)
0.5
6
10
14
19
23
27
TIME(Hours)
Upper 95% CI
Average Moisture
Lower 95% CI