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This is to certify that the

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DEHYDRATION OF ALMONDS

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Major professor

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DEHYDRATION OF ALMONDS

By

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ABSTRACT

DEHYDRATION OF ALMONDS

BY

Rosana Galves Moreira

The drying characteristics of individual almonds and of almond parts (hull, shell, nut) were determined at 41.1-45.7°C and 38-40 percent relative humidity. In addition, the length of time required to keep almonds in a 100°C air oven for moisture content determination was investigated.

High-temperature drying of almonds in-bulk in a new commercial crossflow dryer with differential product-speed in the drying columns was experimentally tested.

Nonlinear curve fitting was used to determine the parameter values in three moisture desorption models. The logarithmic, the Page, and the two-term exponential models were compared. The logarithmic model did not produce an acceptable model. The Page equation fit the data well, but the two term exponential model predicted the experimental data best.

The preferred thin-layer model which was obtained from this study for whole almond at 41.1°C and 38.5 percent relative humidity is:

$$M(t) = 0.08371*exp(-0.6071*t)+0.05741*exp(-0.04023*t)+0.05701$$

and, at 45.7°C and 38.5 percent relative humidity is:

$$M(t) = 0.06606*exp(-0.7202*t)+0.04918*exp(-0.1211*t)+0.06517$$

Determination of moisture content of almonds requires 39 hours in a 100° air-oven.

High-temperature crossflow drying of almonds at 93-100°C produced almonds of good quality.

Chairman, Agricultural Engineering Department

Major Professor

To my mother who has been
a great example in my life
and, to
my grandmother Dolores to
whom I have a great love.

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LIST OF SYMBOLS

A,B	constant
C	degrees Celcius
D	diffusivity coefficient, m^2/hr
EMC	equilibrium moisture content, % d.b.
F	degrees Farenheit
K	Drying constant, hr^{-1}
M	average moisture content, % d.b.
Me	equilibrium moisture content, % d.b.
Mo	initial moisture content, % d.b.
MR	(M-Me)/(Mo-Me) = average moisture ratio
M(t)	moisture content at time, % d.b.
P1, P2, P3	parameters fit by regression
R	radius of sphere, m
RH	relative humidity, percentage
rh	relative humidity, decimal
t	time, hr

CHAPTER I

INTRODUCTION

1.1 Production and Importance of Almonds

The almond (*Amygdalus communis* or *Prummus amygdalus*) is the most extensively used nut in the world. Almonds are grown in temperate zones on several continents and are easily mechanized for harvesting.

Almonds are the earliest-blooming of all nut trees. They are grown only in regions where there is relative freedom from frost during the blooming period and early spring when nuts begin to form. Small immature nuts are even more frost-sensitive than blossoms.

Almonds are best suited to areas with warm, dry summers, in order for the nuts to properly mature. Nuts do not reach maturity if the summers are cool and the humidity is high.

With a few exceptions such as the varieties All-in-One and Garden Prince, almonds require cross-pollinization[1] with another variety to produce a crop.

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[1]Each seed results from the union of a male gamete contained in a pollen grain with a female gamete (the egg), which is contained in the female flower of a complete flower.

Almonds do not tolerate salty soils; they do well in most non-salty soils as long as the ground is well drained.

Table 1.1. Statistics of almonds.

Statistics	Standard	Dwarf
Height at maturity (meter)		
unpruned	12	2-3
pruned	7.6	1.5-2
Spread at maturity with no competition (meter)	9-10	1.5-2
Recommended planting distance (meter)	7-9	3-4
Years to reach bearing age	3	3
Life expectancy (year)	50	50

Source: Western Fruit, Berriers and Nuts (1981).

New plantings of almonds have recently been made on new, fertile, irrigated lands. The plantings have benefited from improved cultural practices, better insect and disease control, and better protection from frost. A tree may begin to bear fruit by the third or fourth year and produces a full crop by the sixth or seventh year. The yield of mature orchards is 750-3000 lb per acre (840 - 3,362 kg per ha) (10-40 lb/tree, 4-18 kg/tree) (Kester, 1979).

Almonds have a pericarp enclosing the kernel; the pericarp consists of an outer fleshy hull and an inner harder shell. After maturing on the tree, the hull splits exposing the shell and allowing faster drying of the nut.

The almond fruit is oval in shape, with a downy succulent covering enclosing a shell in which the edible kernel is located.

When the whole almonds are knocked to the ground, they are often left on the ground several days before being collected and hulled in a hulling machine. The date of harvesting varies from year to year; the harvest in California is about September 1st.

There are two species of almonds: bitter and sweet. There are two classes of sweet almonds: the hard shell and the soft-shell. Bitterness comes from the presence of the chemical amygdalin which breaks down to produce cyanide. Sweet almonds are the most popular.

There are many varieties of sweet almonds. The most frequently grown are: Nonpareil, Ne Plus Ultra, Mission and Thompson. Table 1.2 describes a number of almonds varieties.

Almonds are used in different ways: in snacks and appetizers, in main dishes, soups, vegetables, salads, desserts, cookies and in breads, muffins, candy and chocolates.

Approximately 93% of the almonds in the United States are marketed in a shelled form. They are sold to candy manufacturers, and manufacturers of syrups and pastes (Woodroof, 1979).

The almond-producing countries are Iran, Italy, Morocco, Portugal, Spain and the United States. The almond

Table 1.2. Almond varieties grown in the U.S.A.

VARIETY	FRUIT
All-in-One	Nonpareil-type. Very good to excellent quality, with soft shell and sweet flavor. Shell is well sealed.
Carmel	Kernel is small, thick and long, with soft shell and good flavor.
Garden Prince	Medium kernel is sweet Nonpareil type. Well sealed with soft shell.
Hall	Good-size nut with a hard shell. Bitter flavor, which some find objectionable.
Merced	Shell is paper-thin, well sealed. Small broad kernel.
Mission	Nut is small and round with hard, well sealed shell. Slightly bitter flavor.
Ne Plus Ultra	Nut is large, long and broad with soft shell. Kernel is average quality.
Nonpareil	Large nut with soft, paper-thin shell. Flat, light colored kernel with excellent sweet flavor.
Peerlees	Very hard shell with large nut. Kernel is medium size, good quality.
Price	Soft shell like Nonpareil but plump and poorly sealed.
Thompson	Small nut with soft shell, well sealed and paper-thin. Good quality is plump with a mild, bitter flavor.

Source: Western Fruit, Berriers and Nuts (1981).

production (shelled basis) by country after 1965 (in thousands of metric tons) is shown in Table 1.3.

Table 1.3. Production of almonds in the major producing countries between 1965-1980 (in thousands of metric tons).

COUNTRY	YEAR 1965	1970	1976	1980
United States	36.0	67.5	128.3	146.0
Spain	30.0	29.0	65.0	46.0
Italy	40.0	46.1	16.0	19.0
Portugal	7.7	5.4	5.9	6.0
Iran	7.5	7.0	7.0	7.0
Morocco	7.2	4.0	2.0	2.5

Source: USDA Agricultural Statistics (1965-1980).

In the United States, California is the only important almond-producing state. California produces more almonds than the rest of the world combined. This trend has benefited the United States by further establishing it as the most reliable supplier of high-quality almonds to the rest of the world.

In 1978, the United States accounted for 65% of the world's output of almonds followed by Spain with 20% and Italy with 7.5% of world production; in terms of exports, the United States accounted for over 50% of the total world almond export. Almonds are one of the more important horticultural export crops (King et al., 1983).

Tree nuts have been grown and consumed in the United States since colonial times, but production of almonds on a commercial basis dates back less than 75 years. Traditionally, pecans and walnuts have been the largest domestic tree nut crop. Since 1966 there has been a rapid increase in acres and in the production of almonds (see Table 1.4).

1.2 Drying of Almonds

To maintain quality and avoid losses after harvest, almonds have to be dried to prevent molding, discoloration and breakdown of oil. Drying is necessary also to properly shrink the kernels.

When the whole almond is harvested, each part of the commodity (hull, shell, and nut) has a different moisture

Table 1.4. Almond (shelled basis) production in California, 1966-1980 (in million pounds).

YEAR	PRODUCTION
1966	95.4
1970	149.0
1975	186.0
1980	322.0

Source: USDA Agricultural Statistic (1980).

content. Since almonds are harvested in the 15-25 moisture content range, artificial drying is required.

In all almond producing countries except the United States, the common method of harvesting consists of knocking the almonds off the trees with a pole. At this time the moisture content of the whole almonds is about 10 percent[1] (w.b.). Immediately after harvesting, almonds are dehulled and dried on the ground for several days in the sun; during this time they are turned frequently by hand. When a moisture content of the dried nuts of approximately 5-7 percent (w.b.) is reached, they are stored in the shell until sold.

Conventional on the ground drying of dehulled nuts is usually satisfactory to be able to maintain almond quality in storage. However, the practice is weather dependent.

In the United States forced air drying is often used. It is a safer method for decreasing the excessive moisture of the commodity. The drying process can be divided in two categories: low and high-temperature drying.

Low temperature drying is a common practice for drying almonds, since they are very sensitive to high temperatures. In low-temperature drying a limited amount of heat is added to the ambient air (to about 43.3°C, 110°F). Traditionally,

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[1]Harvesting wet almonds and hulling immediately tends to cause peeling of kernels, and a tendency for the shells to shatter.

wagon dryers are used for drying almonds. They use high airflows and low air temperatures.

High-temperature drying is a faster process. The American almond process industry is beginning to utilize high-temperature dryers (93.3-98.9^{o}C, 200-210^{o}F). To select and design the proper dryer that does not affect the almond quality, it is necessary to analyze the drying behavior of almonds in a thin-layer. This is one of the major objectives of this thesis.

CHAPTER 2

OBJECTIVES

The objectives of this study are:

1. To collect data at small time intervals on whole almond, hull, nut in shell, and nut drying at constant temperature and relative humidity.

2. To determine the most appropriate form of the thin-layer equation for describing drying characteristics of almonds at 41.1-45.7°C and 38.5 percent of relative humidity. The three equations to be tested are:
   a) the logarithmic model,
   b) the Page empirical model, and
   c) the two term exponential model.

3. To determine the almond feasibility in a high-temperature crossflow dryer.

4. To establish the correct length of time for almond moisture content determination in an air oven at 100°C.

Accomplishment of the four objectives will contribute to the solution of the proper design of high-temperature almond dryers.

CHAPTER 3

LITERATURE REVIEW

Nuts are subjected during growth and processing to various forms of deterioration: (1) the loss of texture, color, and flavor; (2) the development of staleness, rancidity, and molding; (3) insect damage (USDA, 1977).

After drying, the moisture content of the almond nuts should be 5-6 percent (w.b.). As long the moisture content is low, molding will not occur at low temperature storage (1-3^{o}C, 32-38^{o}F), and the fats, proteins and carbohydrates will be stable.

Nuts contain more than 50% of fat (see Table 3.1). The high fat content affects the drying and processing of nuts. For optimum stability of the fat, drying has traditionally been done with little heat and much air and storage is at the lowest economical temperature. Processing utilizes heat for the shortest time possible followed by quick cooling (Woodroof, 1979).

3.1 Effect of Moisture Content on Almond Quality

Controlling moisture is the most important factor in the harvesting, storing or processing nuts. Under fair weather conditions the moisture in pecans kernels drops gradually from about 30 to 8 percent (w.b.) before falling of the tree. Nuts from mechanically harvested trees have a higher moisture content compared to these which drop naturally from the tree; the moisture level of pecan kernels may be as high as 30 percent. Regardless, at what moisture pecans are harvested, they need to be dried to a nut moisture level of 4-5 percent by means of artificial drying (Woodroof, 1979).

Table 3.1. Proximate composition of nuts (at proper storage moisture content of the kernels).

COMMODITY	WATER (%)	PROTEIN (%)	FAT (%)	TOTAL CARBOHYDRATES (%)
Almonds[1]	4.7	18.6	54.1	10.1
Brazil nuts[1]	5.3	14.4	65.9	9.2
Macadamia nuts[1]	3.1	8.7	71.4	6.9
Peanuts[2]	5.0	28.5	47.5	13.9
Pecans[1]	3.0	9.4	73.0	7.7
Walnuts (black)[1]	2.7	18.3	58.2	4.0

[1]Chatfield and Adams (1940), Admans (1975)

[2]Freeman et al. (1954)

Macadamia nuts have a moisture content of about 22 percent (w.b.) at harvest (mechanically harvested). To maintain color and flavor, macadamia nuts should be dried to 3-5% moisture before long-term storage (Prichvudhi et al., 1965).

Anigbankpu et al. (1980) dried Ashley walnuts with an initial moisture content of 33.4 percent (w.b.) at 43.3°C (110°F). The final moisture content of 4.8 percent was reached after 25 hours.

Peanuts are harvested at an average kernel moisture content of 18 to 25 percent and are artificially dried to a moisture level of about 10 percent. After artificial drying, the kernel moisture for safe storage should be 7 to 8 percent (Woodroof, 1973).

Rain can cause mold growth of almonds still on the tree. Phillips et al. (1976) found a high moisture content (about 80 percent wet basis) at the time of hull splitting. It decreases until the fruit is removed from the tree at about 20 percent after approximately 35 days. At this time, the nuts, shells and hulls have a moisture content of 7, 15, and 23 percent, respectively.

Almonds should be dehulled and shelled as soon as possible after harvesting to prevent physiological damage. Moist nuts are susceptible to insect invasion and mold damage. The lowest moisture content level at which mold growth has been observed is at 5 percent (Phillips et al., 1976).

The texture of almonds is dependent on moisture content. Very wet almonds are soft and pliable; very dry ones are hard and brittle (King et al., 1983).

The equilibrium moisture content (EMC) determines the minimum moisture content to which a biological product such as almonds can be dried under a given set of drying conditions. It is dependent upon the humidity and temperature conditions of the environment, and upon the variety and maturity of the crop (Brooker et al., 1981).

The EMC is important in the process of drying a biological product. Experimental values of moisture equilibria for nuts and peanuts obtained from the literature, are tabulated in Table 3.2.

Table 3.2. Equilibrium moisture content (w.b.) of different nuts.

COMMODITY	TEMPERATURE °F(°C)	RELATIVE HUMIDITY,% 40	50	60	70	80	Ref.
Almond nut	71.6 (22)	3.0	3.5	4.0	5.5	7.0	(1)
Cashewnuts whole	80.6 (27)			7.6	9.4	11.4	(4)
Peanut pod	50.0 (10)	6.1	7.1	8.6	9.8	11.9	(2)
Peanut nut	50.0 (10)	5.5	6.0	6.6	7.3	9.0	
Walnuts whole	80.6 (27)	6.1	8.2	10.9	14.1	18.6	(3)

(1) Phillips et al. (1976), (2) Beasley (1962), (3) Anigbankpu et al. (1980), (4) Okwelogu et al. (1969).

According to Prichavudhu et al. (1965) macadamia nuts dried at high temperatures can develop dark brown-centers.

The effect of high temperatures in producing brown-centers is also dependent on the moisture content. Low-moisture content nuts tolerate high-temperature drying better than high moisture content nuts. At elevated temperatures, the sugars in macadamia nut are reduced. The reducing sugar content is higher in the brown-center than in the light-colored outer layers.

Woodroof (1979) dried pecan meats at temperatures of 48.9°C (120°F) to 60°C (140°F); a dry and slightly tough texture, and a slightly cooked flavor developed, resulting in a stale taste during storage. He concluded that drying meats with hot air is fast, but the quality of the meats is adversely affected when the meats are dried above 48.9°C (120°F).

King et al. (1983) confirmed that a high percentage of moisture in mature almond nuts is the cause of brown-center in high-temperature dried almonds.

Peanuts dried at temperatures above 35°C (95°F) have an off-flavor; such treatment causes the skin to slip during shelling. If peanuts are over-dried to below 7 percent w.b., they may damage when shelled. If air is not forced through the peanuts in a volume sufficient to dry the peanuts at a reasonable rate, the peanuts may be damaged by mold (Dickens, 1957).

3.2 Methods for Determining the Moisture Content of Almonds

The design of a dryer for biological products requires a knowledge of the heat and moisture loss of the product. The heat and moisture loss depends upon several factors such as: the species, maturity, harvest conditions, degree of injury and drying conditions.

The methods for determining the moisture content of biological product may be divided into direct and indirect. The oven-method, a direct method, is most frequently used for determining the moisture content of biological products.

The general procedure consists of:

(1) grinding the product and drying it in an air-oven for 1 to 2 hours at 130°C (260°F);

(2) placing the product in an oven at 100°C (212°F) for 72 to 96 hours.

In the case of almonds which have a high fat content, it is preferred to use a low temperature and short time to avoid weight loss due to a loss of dry matter.

King et al. (1983) used the AOAC (1980) method for determining the moisture content of Nonpareil almonds. This method consists of:

(1) passing a sample through a food chopper three times and mixing it after each grinding;

(2) spreading 5-10 grams of the prepared sample evenly in a metal dish provided with tightfitting cover, and drying it for 6 horus at 70 $\pm$ 1°C (158 $\pm$ 1°F) under pressure (100 mmHg; 13.3 KPa);

(3) during drying, admitting to the oven a slow current of air (ca 2 bubbles/sec) dried by passing through H_2SO_4;

(4) replacing the cover, cooling dish in dessicator and weighing.

The vacuum oven method has been used for determining the moisture content of nuts. Prichavudhi et al. (1956) determined the moisture content of macadamia nuts by drying 5-g of nuts at 70°C(158°F) in a vacuum of 25mm of mercury for 24 hours.

The same procedure was followed by Anigbankpu et al. (1980) and by Beuchat (1973) to determine the moisture content of Ashley walnuts and of pecans, respectively.

Moisture of Spanish peanuts was determined by Brusewitz et al. (1976) by drying a 40 - 50 grams sample of kernels for 3 hours in an air oven at 130°C (266°F).

Okwelogu et al. (1969) used a distillation method to determine the moisture content of cashew nuts. Toluene (b.p.110°C) was employed as the entraining solvent.

Chinnan (1981) determined the moisture content of pecans (kernel and shells) by grinding them separately in a blender and drying them in an oven at 110°C (230°F) for two and one half hours.

3.3 Thin-Layer Drying Equations for Nuts

Thin-layer equations are of critical importance in deep bed drying models (Bakker-Arkema et al., 1974). The equations are obtained from thin-layer experiments in which a small amount of product is dried. In order to accurately simulate the multi-layer process, an accurate equation describing the moisture behavior of a thin-layer of material is essential.

A considerable amount of work has been reported in the literature on thin-layer drying studies of biological products. The studies are fundamental to the development of mathematical drying simulation models. Most of the previously reported work has been conducted on thin-layer drying of peanuts, walnuts and pecans but no information is available on almonds (King et al., 1983).

Several models have been proposed to describe the drying characteristics of biological products. Lewis (1921) proposed a logarithmic model. This model is analogous to Newton's law of cooling and assumes that the rate of moisture loss surrounded by a medium at constant temperature is proportional to the difference between the moisture content and its equilibrium moisture content:

$$dM/dt = K(M-Me) \qquad (1)$$

After integrating, equation (1) comes:

$$MR = \exp(-Kt) \qquad (1a)$$

where:

MR = (M-Me)/(Mo-Me) = average moisture ratio, dimensionless

M = average moisture content, db

Me = equilibrium moisture content, db

Mo = initial moisture content, db

t = time, hr

K = drying constant, hr^{-1}

A second model used by several investigators is the diffusion model. The liquid diffusivity model is the most widely used. This considers the diffusivity of water to occur in the form of liquid. For spherical bodies liquid diffusion can be represented by (Brooker et al., 1974):

$$MR = (6/\pi^2) \sum_{n=1}^{\infty} (1/n^2) * \exp(-n^2 * \pi^2 * D\, t)/(R^2) \qquad (2)$$

where:

R = radius of sphere, m

D = diffusivity of water, m^2/hr

Chinnan and Young (1977) employed the diffusion equation in drying peanuts. Diffusivities of peanut kernels and hulls were calculated at four bulb temperatures (26.7 to 43.3°C, 80 to 110°F) and four dew point temperatures (8.0 to 22.8°C, 46.4 to 73°F). Diffusivity as an exponential function of absolute dry bulb temperature was expressed as

$$D = \exp(D_o + A/T) \qquad (3)$$

where the values of D_o and A are tabulated in Table 3.3.

Chinnan (1981) concluded that the diffusion model was suitable for modeling the drying of in-shell pecans.

Henderson (1974) reported that thin-layer drying of many biological products can be represented by a two or three term exponential model of the form:

Table 3.3. Values of D_o and A for peanuts in equation 3.

THIN-LAYER MODEL	DIFFUSIVITY	POD COMPONENT	D_o $m^2/h(ft^2/hr)$	A $m^2\text{-}^oC/h(ft^2\text{-}^oF/hr)$
Vapor-liquid	vapor	kernel	-10.77(-3.28)	2591.34(789.84)
		hull	-16.50(-5.03)	3674.27(1119.91)
	liquid	kernel	0.59(0.18)	-5228.42(-1593.62)
		hull	3.54(1.08)	-6341.68(-1932.94)

Source: Chinnan and Young (1978).

$$MR = Ao \exp(-K_o t) + A_1 \exp(-K_1 t) + \ldots \qquad (6)$$

To use equation (6), Henderson suggested of regression to fit the data.

Anigbankpu et al. (1980) employed a form of the Henderson equation to predict the thin-layer drying of in-shell Ashley walnuts at temperatures between 21°C (80°F) and 43.3°C (110°F) and relative humidities between 25 and 76 percent (see Figure 1). The constant Ao was found to be about 1 with only the first term to be effective. The resulting equation was therefore equation (1a), with the following values for K and Me:

$$K = \exp(-0.681 + 0.011Mo + 0.95 \ln Mo + 0.000152 (1.8T + 32.2)^2) \quad (7)$$

$$Me = (\ln(1.0-rh)/(-0.000031(T + 3095))) \quad (8)$$

where:

$T = {}^{o}C$

Mo = percent, db

rh = decimal

Equations (1a), (7) and (8) were adequate for predicting drying rates of Ashley walnuts, but they are not suitable to model deep bed drying walnuts (Rumsey et al., 1979).

Many investigators have used the Page equation for modeling the drying of biological products (Page, 1949):

$$MR = \exp(-Kt^n) \quad (9)$$

Page added an empirical exponent to time in equation (1a). Equation (9) is also known as the modified form of the logarithmic model.

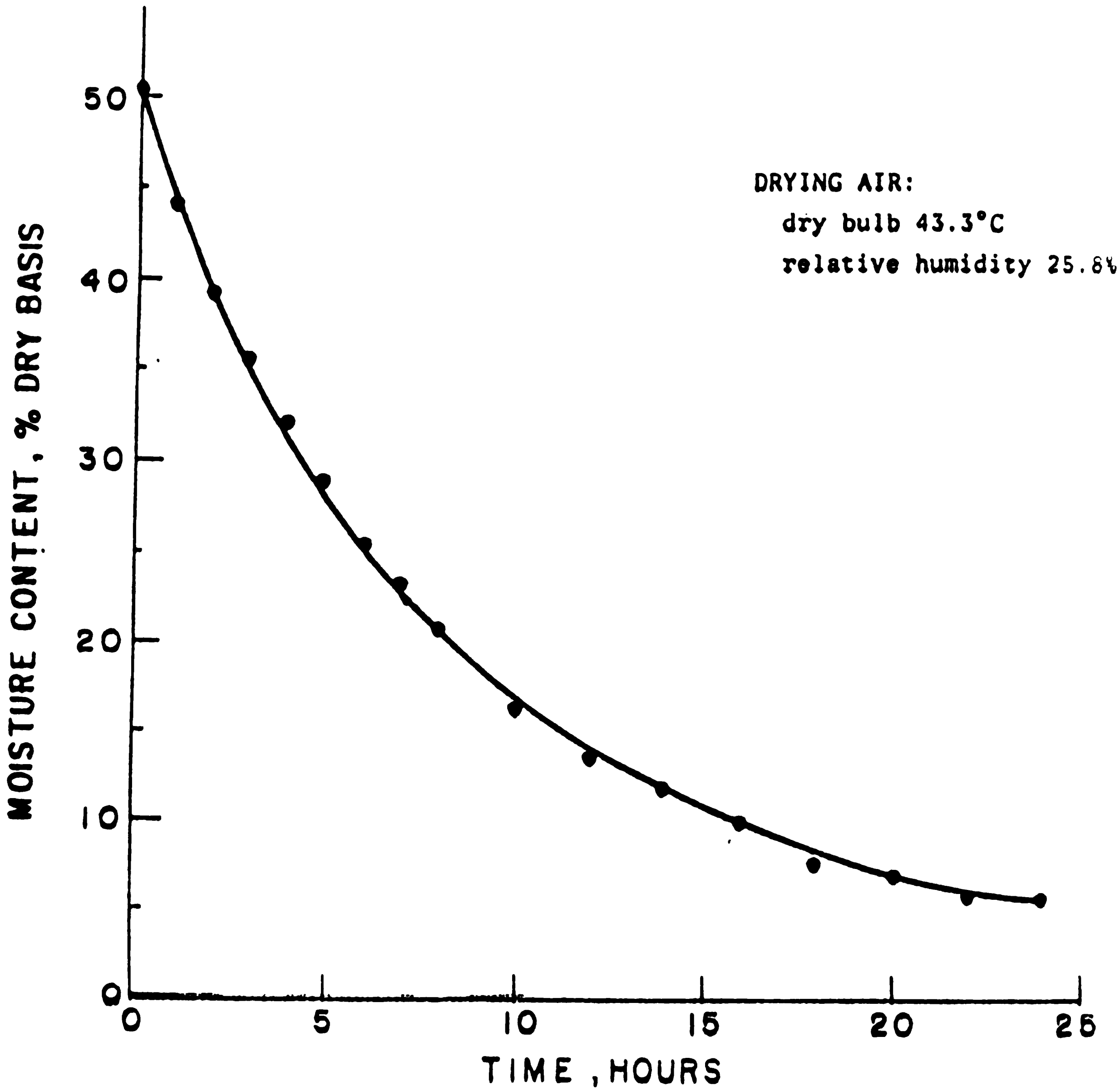

FIGURE 1: Drying curve for Ashley walnuts (Anigbankpu et al., 1980).

CHAPTER 4

EXPERIMENTAL INVESTIGATIONS

Nonpareil almonds grown in Chico, California were the major variety used in this investigation.

Data was collected from two sources:

(1) - a differential-speed crossflow dryer tested in a commercial almond processing plant;

(2) - a thin-layer drying apparatus.

The almonds were air-frighted to Michigan State University and stored in plastic bags at 10°C (40°F).

4.1 Thin-Layer Drying Tests

A series of six thin-layer drying tests was performed in the Agricultural Engineering Processing laboratory at Michigan State University during the winter and spring of 1983. The tests were conducted in an experimental thin-layer dryer designed by Byler (1983).

The different drying rates of the whole and of the individual almond parts were determined.

4.1.1 Dryer Design

The drying chamber for the thin-layer experimental studies is constructed from plywood. It measures 1.60 m long, 0.50 m deep and,0.30 m high. The product is placed in the chamber loaded on two trays (two trays in each weight transducer) of 0.20 m by 0.30 m made of aluminum screen with a lip of about 0.01 m around the edge to hold the sample on the tray. The trays are attached to the load cells which are located 1.05 m from the front of the chamber.

An Aminco-aire conditioning unit (model J4-5460) is used to deliver air with a precise by controlled temperature and relative humidity. The outlet port of the air conditioning unit is connected to the study chamber of the dryer. The duct from the air conditioning unit to the chamber is insulated with fiberglass. The air flow across the almonds is 26.7 cm/sec.

A weighing system was designed to continuously monitor the weight of samples without removing them from the chamber. Figure 2 is a schematic of the dryer.

4.1.2 Instrumentation and Procedure

To initialize the drying process, the equipment is turned on and the water temperature is set. Half an hour is allowed for the equipment to stabilize. Before loading the almonds on the trays, the data collection system is turned on.

The almonds used in the tests are removed from storage and weighed in a container. About 100 grams of product is spread on each tray.

The microcomputer controls the drying conditions during each test. The following data are recorded each minute:

the weight of each transducer (two in the total);
the temperature at 3 places near the samples;
the temperature at the entrance of the chamber;
the temperature at the air heater;
the time.

Each test is allowed to run for at least 22 hours. Table 4.1 shows conditions of the various tests.

At the end of a test, the samples on the two trays of an individual transducer are combined and weighed, and the final moisture is determined. To determine the moisture content of the sample during a test, it is assumed that the dry weight of a sample does not change.

The dry matter content of the almond in each transducer is calculated separately and the two dry matter weights are averaged for each transducer.

Data is recorded on cassette tapes and transferred to a floppy disk. The data reduction program converts the time from days, hours, minutes, and seconds, to the hours and seconds since the beginning of the test. It also converts the number representing the weights on each transducer to moisture content dry basis, and the temperature numbers to

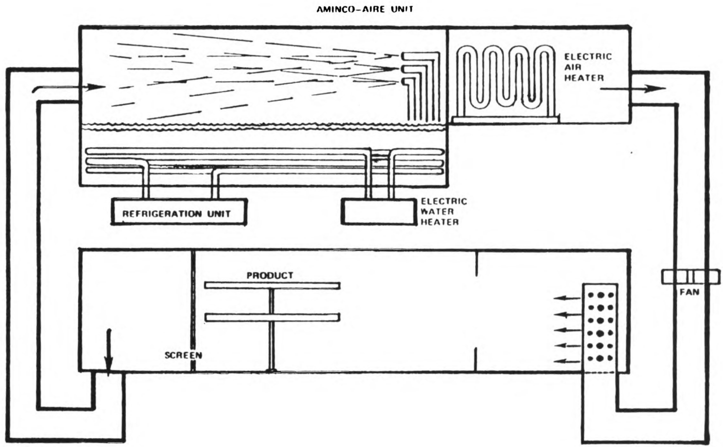

FIGURE 2: Thin-layer drying equipment.

temperature in Celcius. The results are stored as integers.

Next the data are converted to ASCII for transmission to the Cyber for the data analysis.

TABLE 4.1: Test condition for thin-layer almonds drying.

TEST NUMBER	WATER TEMP. °C(°F)	RH. (%)	CHAMBER TEMP. °C(°F)	INITIAL MC (%d.b.)	COMMODITY
Test 1A	17 (62.6)	38.5	35.5(95.9)	14.3	whole almond
1B				14.4	whole almond
Test 2A	27 (80.6)	38.5	45.7(114.3	18.3	whole almond
2B				17.9	whole almond
Test 3A	22 (71.6)	38.5	41.1(106)	20.4	whole almond
3B				19.5	whole almond
Test 6A	22 (71.6)	38.5	41.1(106)	16.4	nut in shell
6B				15.8	nut in shell
Test 7A	22 (71.6)	38.5	41.1(106)	28.3	hull
7B				26.8	hull
Test 8A	22 (71.6)	38.5	41.1(106)	11.9	nut
8B				12.3	nut

4.2 Deep-Bed Drying Tests

A series of three almonds drying tests was conducted in a high-temperature crossflow dryer equipped with differential product speed and tempering (manufactured by Blount, Inc., Montgomery, Alabama) in California, during September of 1982.

The feasibility of high-temperature almond drying was investigated.

4.2.1 Dryer Design

Figure 3 is a schematic of the dryer.

The almonds flow from the wet hopper bin (A) through the outer tapered columns (B) to the dual variable speed discharge feed rolls (H). The partially dried almonds are transported via a bucket elevator to a tempering hopper (D). The almonds move after tempering through the inner tapered drying columns (E), and finally through the cooling columns (F). The exhaust air from the second set of drying columns along with the cooling air is recirculated.

The unique features of Blount almond dryer include the tapered columns, the variable speed discharge augers and the tempering hopper. The tapered columns enhance the airflow through the wetted almonds. The variable speed discharge augers allow almonds nearest to the air inlet to move faster than almonds on the air outlet side of the column.

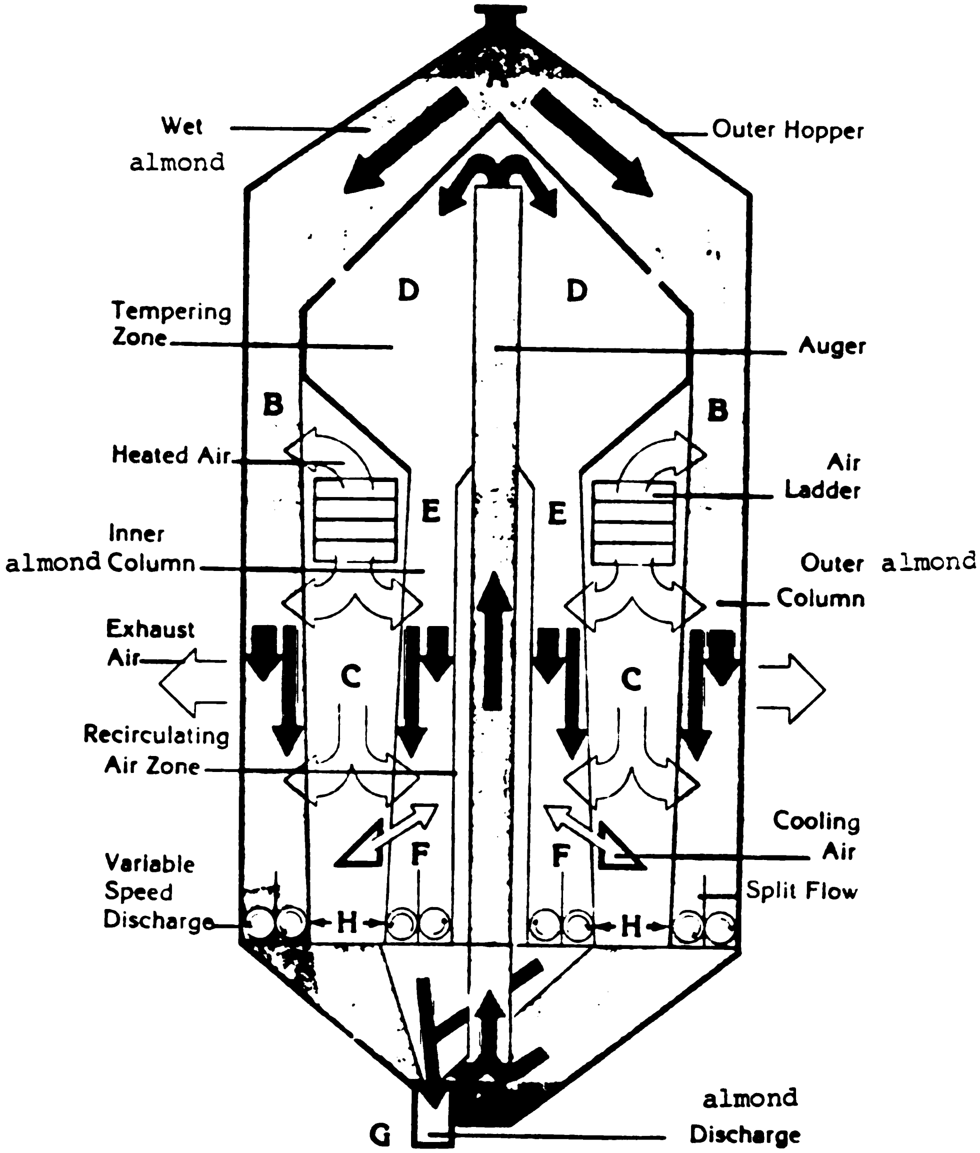

FIGURE 3: Schematic of high-temperature column-type almond dryer.

The almond drying process is separated in two stages, being interrupted by about a one hour in the tempering zone, which minimizes kernel moisture and tempering gradients and improves product quality and dryer energy efficiency (Bakker-Arkema et al., 1983).

The dryer is designed with a heat exchanger for indirect heating of the air by natural gas or fuel oil. The airflow is furnished by one 60 HP centrifugal fan.

4.2.2 Procedure

For the performance evaluation of the almond dryer, the following parameters need to be measured:

1 - product initial moisture content before and after drying;

2 - product initial and final moisture content;

3 - product initial and final test weight;

4 - product initial and final quality;

5 - drying capacity in wet bushels per hour (ton/hr);

6 - ambient and dry temperature, and relative humidity;

7 - airflow rate;

8 - energy consumption fuel and electricity.

Three tests were conducted using the differential speed crossflow dryer. The temperature of the inlet air for TestC 1 was 96^{o}C (205^{o}F), for TestC 2 93.3^{o}C (200^{o}F) and for TestC 3 98.8^{o}C (201^{o}F). The air flow rate was 57,143 cmm (52,000 cfm) for TestC 1 and TestC 2, and 41,758 cmm (38,000 cfm) for TestC 3.

The ambient conditions were:

TestC 1 - dry bulb temperature, 21.1°C (70°F)
relative humidity, 90%

TestC 2 - dry bulb temperature, 25.6°C (78°F)
relative humidity, 38%

TestC 3 - dry bulb temperature, 26.7°C (80°F)
relative humidity, 38%

4.3 Moisture Content Determination

Samples of whole almonds were dried in an air-oven at 100°C (212°F) for 20, 24, 39, 48, and 96 hours to establish the correct length of time for moisture content determination of almonds. The moisture content was determined on a dry weight basis for each sample from the weights of a 12 gram portion before and after over-drying for 39 hours at 100°C (212°F).

CHAPTER 5

DATA ANALYSIS FOR THE THIN-LAYER DRYING TESTS

The data set was collected on several files. The first step in the analysis was to plot the moisture contest vs. time for each test.

Upon examination, data from Test 1 was observed to have irregularities. The tests not reported are those for which not enough data are obtained due to instrument malfunction.

Three different equations were tested to determine the most appropriate equation for thin-layer drying of almonds:

(a) the logarithmic model,

(b) the Page equation,

(c) the two term exponential equation.

The temperature and relative humidity are assumed to be constant, i.e., the model is correct only at one combination of relative humidity and temperature. Because that the temperature range the equipment is between 17°C (62.6°F) to 50°C (122°F), it was not possible to perform thin-layer tests at temperatures over 50°C. At constant temperature and relative humidity, the equations become:

- the logarithmic model:

$$M(t) = (Mo-EMC)*\exp(-Kt)+EMC \quad (10)$$

- the Page equation:

$$M(t) = (Mo-EMC)*\exp(-Kt^n)+EMC \quad (11)$$

- the two term exponential model:

M(t) = (Mo-EMC)*exp(P1*exp(P2*t)+P3*exp(P4*t))+EMC (12)

The parameters Mo and EMC are considered to be unknown. Equations (10), (11) and (12) are intrinsincally nonlinear.

Nonlinear regression techniques were used to obtain values of the parameters by fitting the three equations to the experimental data. To determine the parameters, equations (10), (11) and (12) were transformed into:

(a) M(t) = P1*exp(P2*t)+P3 (13)

(b) M(t) = P1*exp(P2*exp(P3*ln(t)))+P4 (14)

(c) M(t) = P1*exp(P2*t)+P3*exp(P4*t)+P5 (15)

The nonlinear regression technique chooses the set of data and produces the lowest residual means square. This results in a best fit of the observed values.

The statistic packages BMDP3R and BMDPAR (Dixon, 1981) were used to estimate the parameters of Eqns. (13), (14) and (15). The program BMDP3R employs a modified Gaus-Newton algorithm. The second program, BMDPAR, estimates the parameters of any nonlinear function by a pseudo Gaus-Newton algorithm. Both programs compute the weighted least-square estimates. The parameters are estimated by an iterative algorithm. At each iteration the programs print the residual sum of squares and the estimates of the parameters. Once the parameters estimates are determined, the program prints estimates of the asymptotic standard deviations of the parameter estimates, and of the correlations between them.

Both programs can plot the residuals and predicted values against other variables.

5.1 Residuals

The residuals are the variation of the measured dependent variable which the model fails to explain. If the model is correct then these are the errors and the residuals provide the best estimate of the error in the data.

An examination of the residuals is an important part of regression analysis, because it helps to detect any inconsistency between the data and the model (Bhattachryya et al., 1977).

A plot of the residuals vs. the predicted values or of the residuals vs. time, often helps to detect the inadequacies of an assumed relation. It the points form a horizontal band around zero, no abnormality can be assumed.

CHAPTER 6

RESULTS AND DISCUSSION

The results of this study will be presented in the following order:

(1) thin-layer drying results,

(2) deep-bed drying results.

6.1 Thin-Layer Drying Results

The parameters obtained with the logarithmic model for the runs are shown in Table 6.1 along with the residual means square associated with the fits.

Tables 6.2 and 6.3 show the results obtained by fitting the Page model and the two term exponential model to the experimental data, respectively.

The two term exponential model fits the data significantly better than the one term model. The residual mean square is at least an order of magnitude lower for the two term than for the logarithmic model.

The Page equation works fairly well at predicting the observed values, as can be seen from the residual mean square values in Table 6.2.

TABLE 6.1: Results obtained by fitting the logarithmic model to the test data.

TEST NUMBER	P1	P2	P3	RESIDUAL MEAN SQUARE
Test 2A	0.0934	-0.221	0.0715	0.172E-04
2B	0.103	-0.292	0.0641	0.855E-05
Test 3A	0.0998	-0.171	0.0742	0.425E-04
3B	0.0949	-0.165	0.0738	0.374E-04
Test 6A	0.0702	-0.290	0.0726	0.132E-04
6B	0.0702	-0.204	0.0686	0.111E-04
Test 7A	0.173	-0.629	0.102	0.109E-04
7B	0.158	-0.701	0.103	0.106E-04
Test 8A	0.0689	-0.179	0.0472	0.133E-05
8B	0.0750	-0.158	0.0457	0.927E-06

TABLE 6.2: Results obtained by fitting Page's equation to the test data.

TEST NUMBER	P1	P2	P3	P4	RESIDUAL MEAN SQUARE
Test 2A	0.1123	-0.507	0.567	0.0665	0.284E-05
2B	0.119	-0.491	0.700	0.0623	0.287E-05
Test 3A	0.160	-0.538	0.430	0.0583	0.708E-05
3B	0.151	-0.507	0.437	0.0577	0.717E-05
Test 6A	0.109	-0.665	0.481	0.0640	0.318E-05
6B	0.103	-0.632	0.527	0.0621	0.344E-05
Test 7A	0.185	-0.758	0.794	0.101	0.338E-05
7B	0.170	-0.841	0.762	0.102	0.314E-05
Test 8A	0.0854	-0.209	0.697	0.0340	0.486E-06
8B	0.0814	-0.178	0.849	0.0409	0.760E-06

TABLE 6.3: Results obtained by fitting a two-term exponential model to the test data.

TEST NUMBER	P1	P2	P3	P4	P5	RESIDUAL MEAN SQUARE
Test 2A	0.0674	-0.713	0.0485	-0.0928	0.0670	0.175E-05
2B	0.0481	-1.042	0.0682	-0.194	0.0630	0.303E-05
Test 3A	0.0855	-0.650	0.0578	-0.0456	0.0595	0.220E-05
3B	0.0823	-0.560	0.0584	-0.0334	0.0528	0.211E-05
Test 6A	0.0456	-1.977	0.0507	-0.172	0.0693	0.264E-05
6B	0.0407	-2.081	0.0528	-0.193	0.0662	0.285E-05
Test 7A	0.0562	-2.225	0.127	-0.473	0.101	0.304E-05
7B	0.0619	-2.148	0.105	-0.485	0.102	0.324E-05
Test 8A	0.0123	-1.513	0.0646	-0.107	0.0421	0.518E-06
8B	0.0102	-1.551	0.0737	-0.137	0.0444	0.523E-06

In most cases, the two term exponential model fits better than the Page equation. In the case of 2B, 7B and 8A the fit of data is as good with one model as with the other. Only in the case of 3A and 3B is the two term exponential model clearly better than the Page equation.

The plots of residuals were examined[1]. Figure 4 shows the residuals from Test 3A plotted against predicted moisture content for the Page equation. The plot shows that the residuals form a systematic pattern. Instead of being randomly distributed around the y-axis (around zero), they tend first to decrease and then to increase. This leads to the suspicion that the model is inadequate. Figure 5 shows similar results for Test 3B.

Figures 6 and 7 show the residuals from tests 3A and 3B plotted vs. predicted moisture content, respectively, for the two term exponential model. The plots do not seem to signal any appreciable violation of the assumptions. In Figures 8 and 9 the residuals from tests 3A and 3B are plotted vs. time. They show a pattern. Byler (1983) concluded that this pattern is caused by something that was measured during the first half hour and was not accounted for the model. On the other hand, the residuals are quite low, most of the data points in the two test lie between -0.002 to +0.002. Therefore, the two term exponential model fits

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[1]Because the whole almonds constitute 90% of the product entering a commercial dryer, only the whole almond tests will be analyzed in detail.

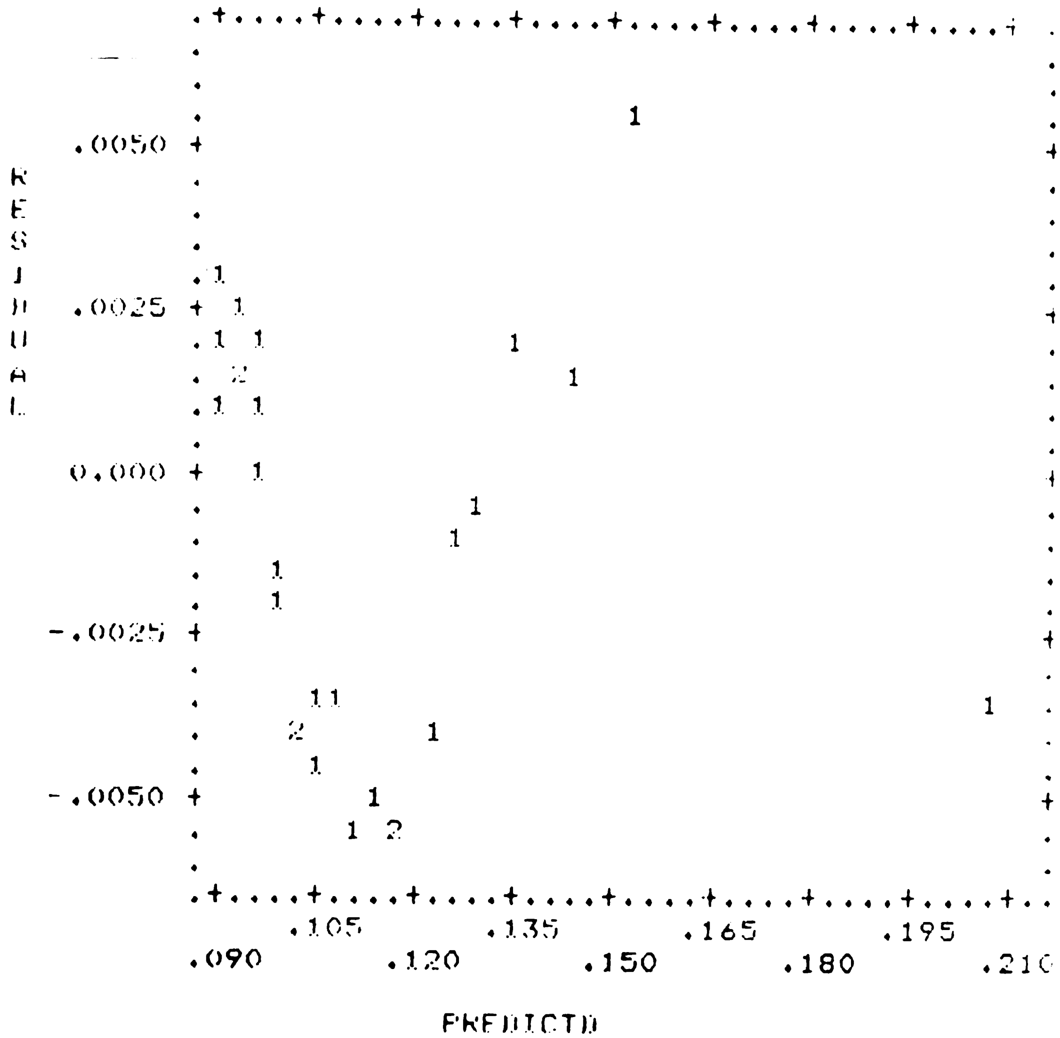

FIGURE 4: Residuals of test 3A vs. predicted moisture content, dec. d.b., Page model.

In the plot the numbers indicated the number of data points which should be plotted at the same place on the paper.

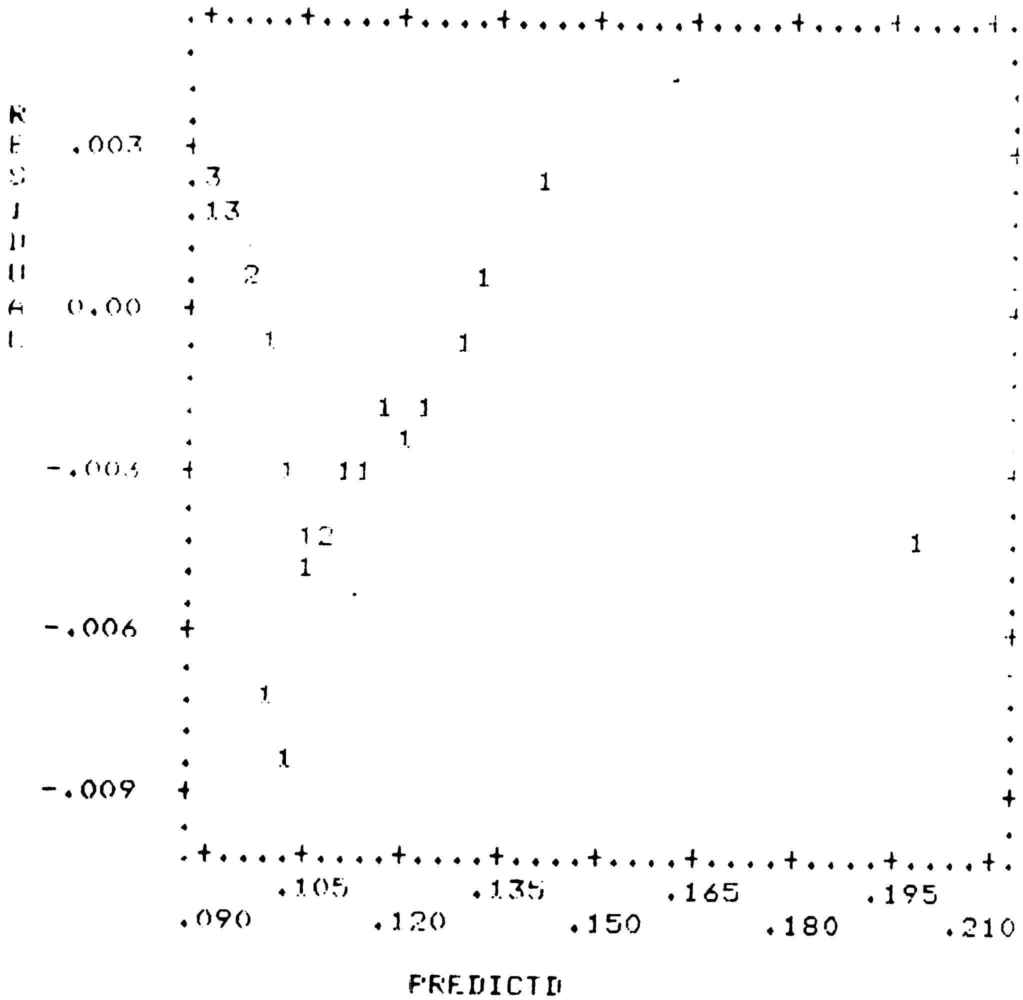

FIGURE 5: Residuals of test 3B vs. predicted moisture content, dec.d.b., Page model

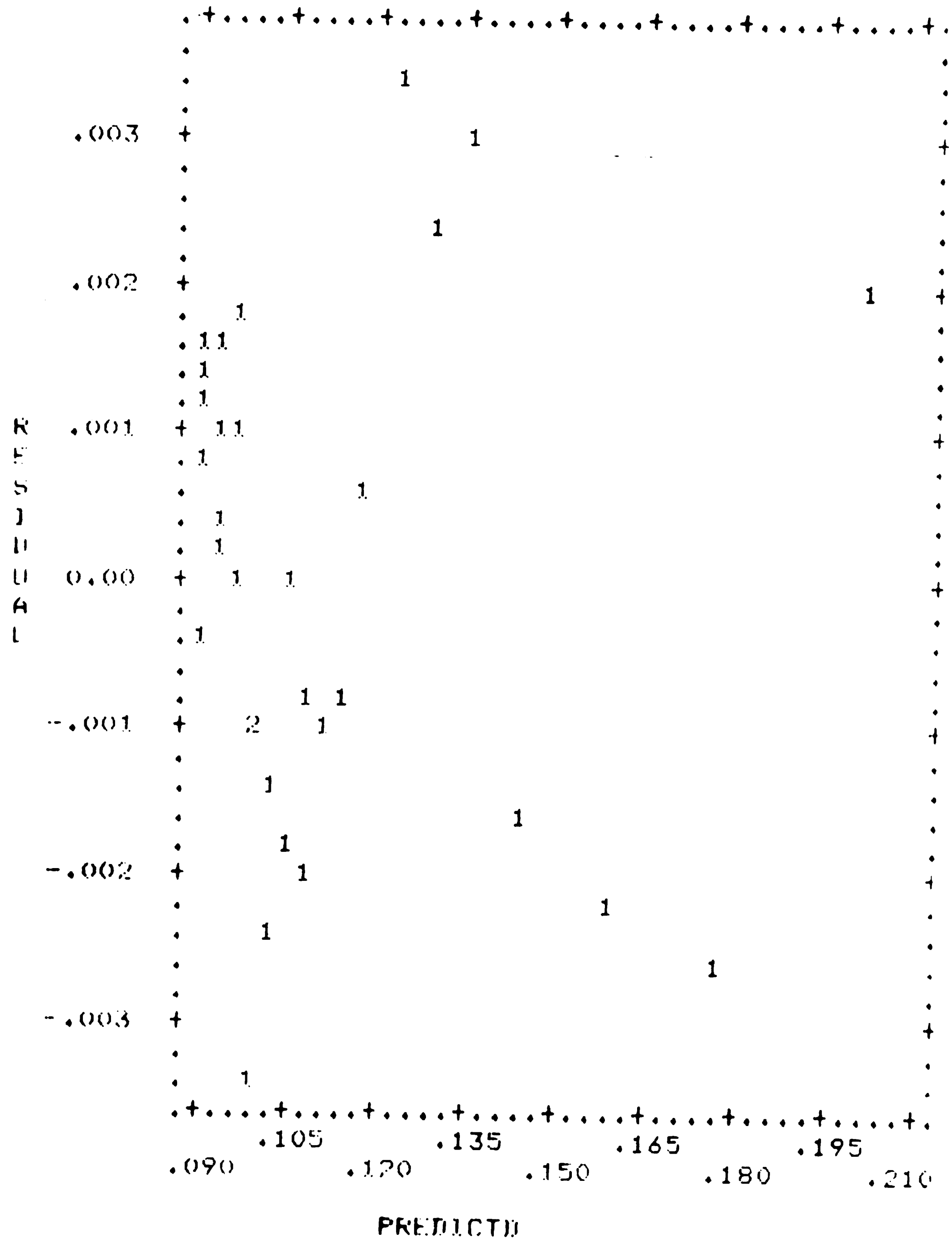

FIGURE 6: Residuals of test 3A vs. predicted moisture content, dec.d.b., two term exponential model.

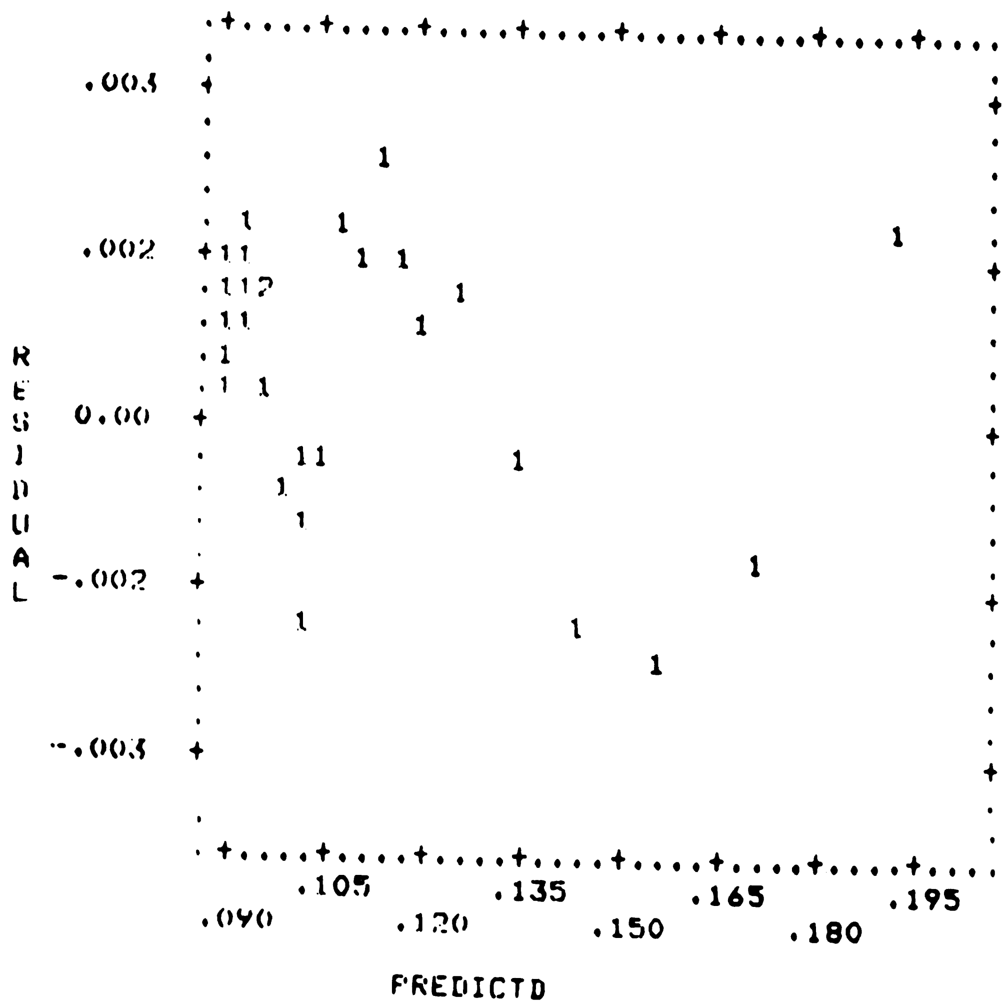

FIGURE 7: Residuals of test 3B vs. predicted moisture content, dec.d.b., two term exponential model.

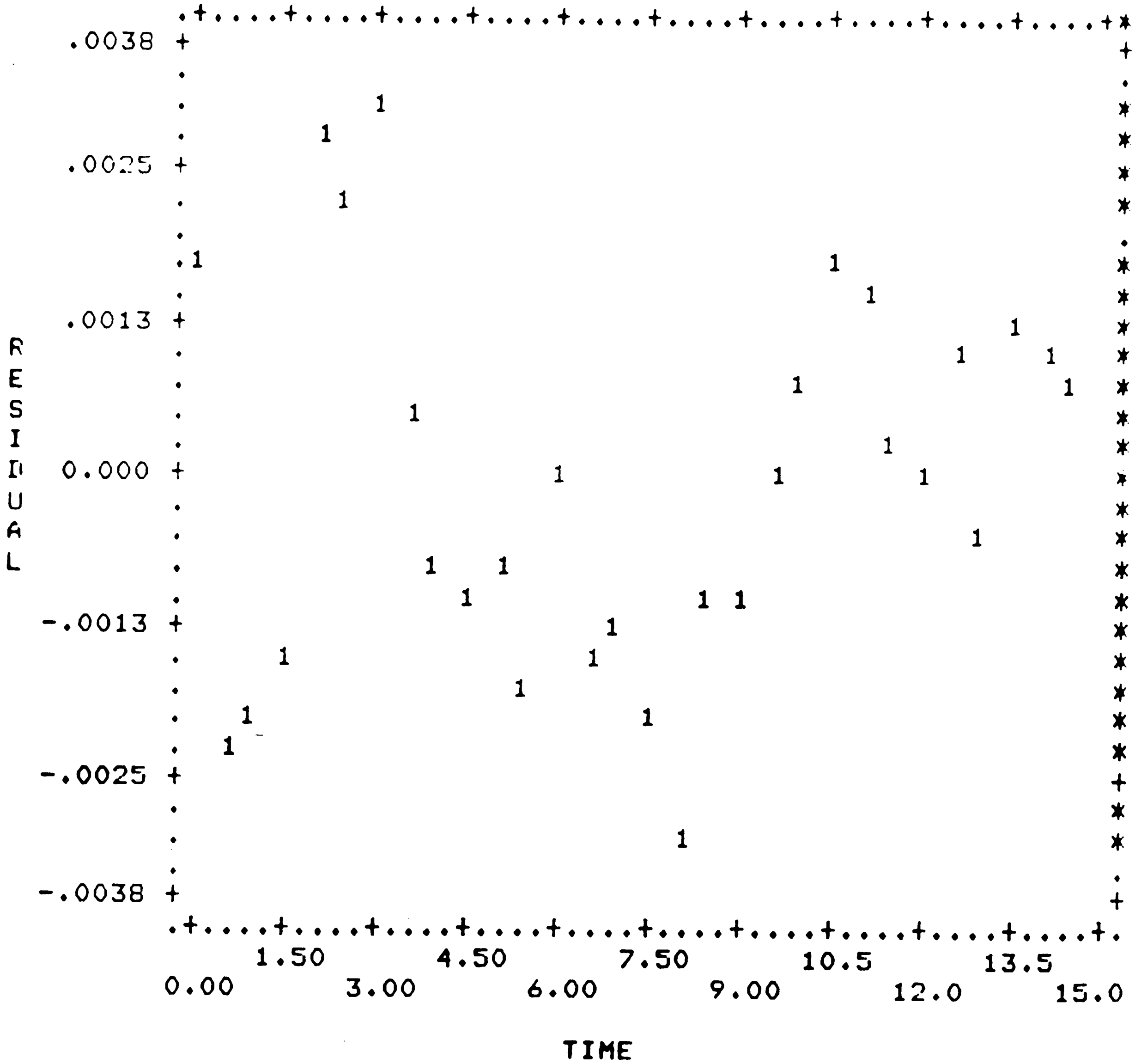

FIGURE 8: Residuals of test 3A vs Time (hours), two term exponential model.

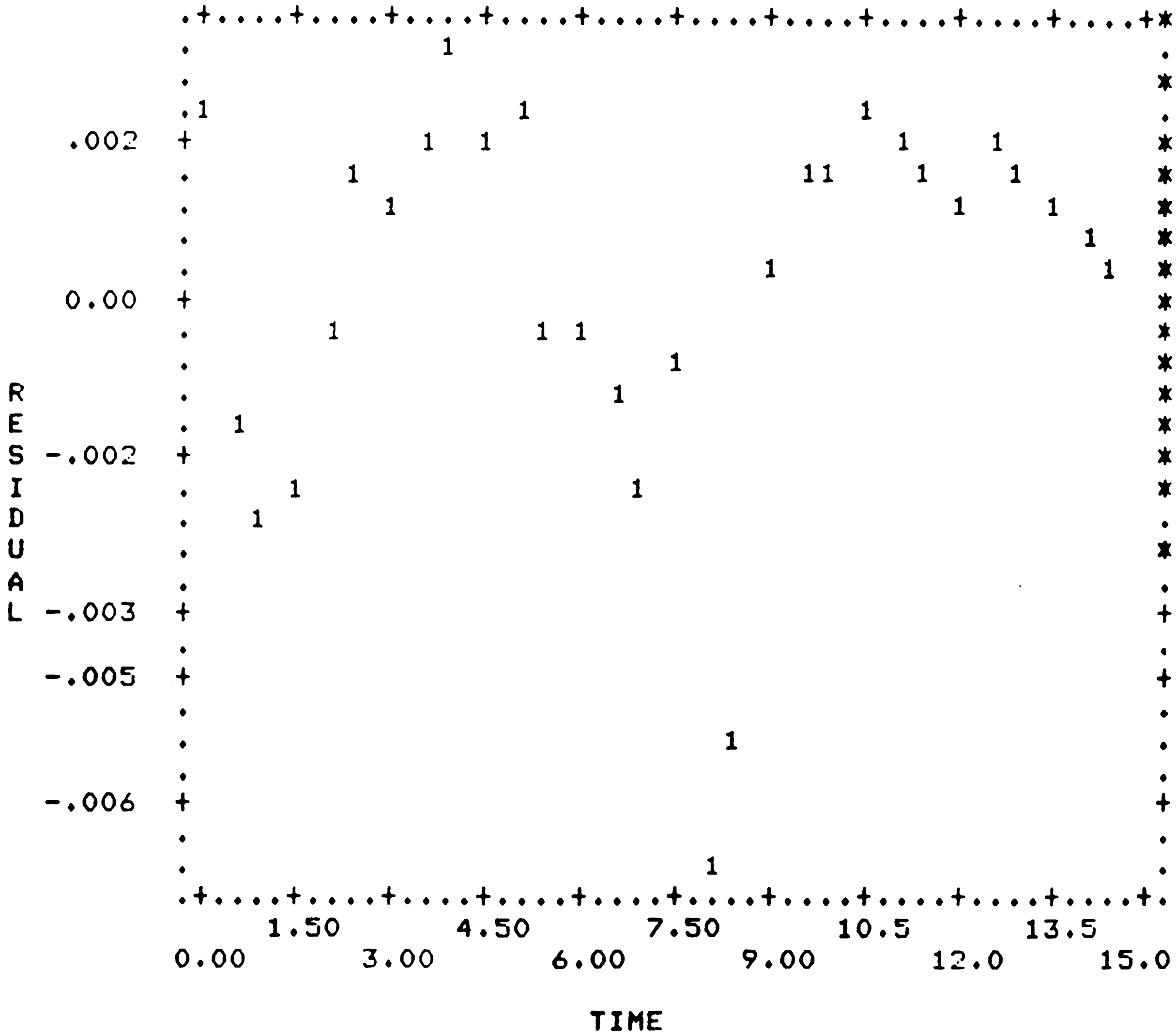

FIGURE 9: Residuals of test 3B vs. Time (hours), two term exponential model.

the data well.

The predicted drying curves using the results obtained in this analysis were compared with experimental drying curves as shown in Figure 10 to 12.

Figure 10 shows the drying behavior at 41.1°C (106°F) and 38.5 percent relative humidity of the whole almond, the hull, the nut and shell, and of the nut. As shown, the logarithmic model fails to adequately describe the drying behavior over the entire drying period. By comparing the predicted and experimental values of the whole almond curve in Figure 10, it can be seen that the logarithmic model underestimates the drying rate over the first part of the curve and overestimates it over the second part of the curve.

Similar results are shown in Figure 11, in which the Page equation is compared with the experimental data. The model is acceptable to describe thin-layer drying of almonds. It fits the data better than the logarithmic model. The exponent on time causes the exponential decay to curve slightly, increasing the slope at small times and decreasing the slope at large times.

The two term exponential model presents the best agreement between observed and predicted values as showing in Figure 12. The best thin-layer equations obtained for whole almond are:

at 41.1°C and 38.5 percent relative humidity,

$$M(t) = 0.0\ 8371*\exp(-0.6071*t)+0.05741*\exp(-0.04023*t)+0.05701$$

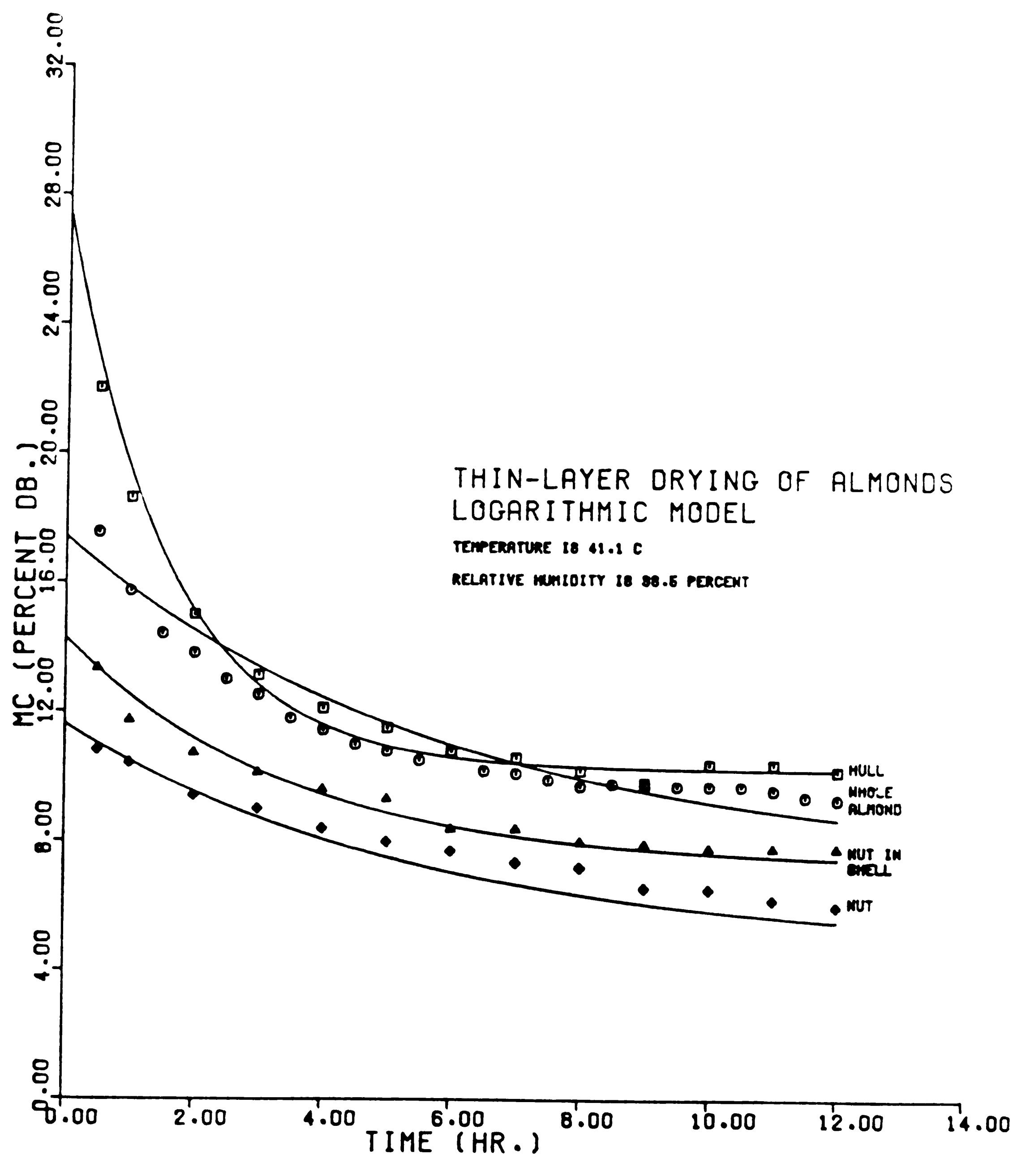

FIGURE 10: Predicted and experimental drying curves of tests 3A, 6A, 7A and 8A, using logarithmic model with constants as given in Table 6.1.

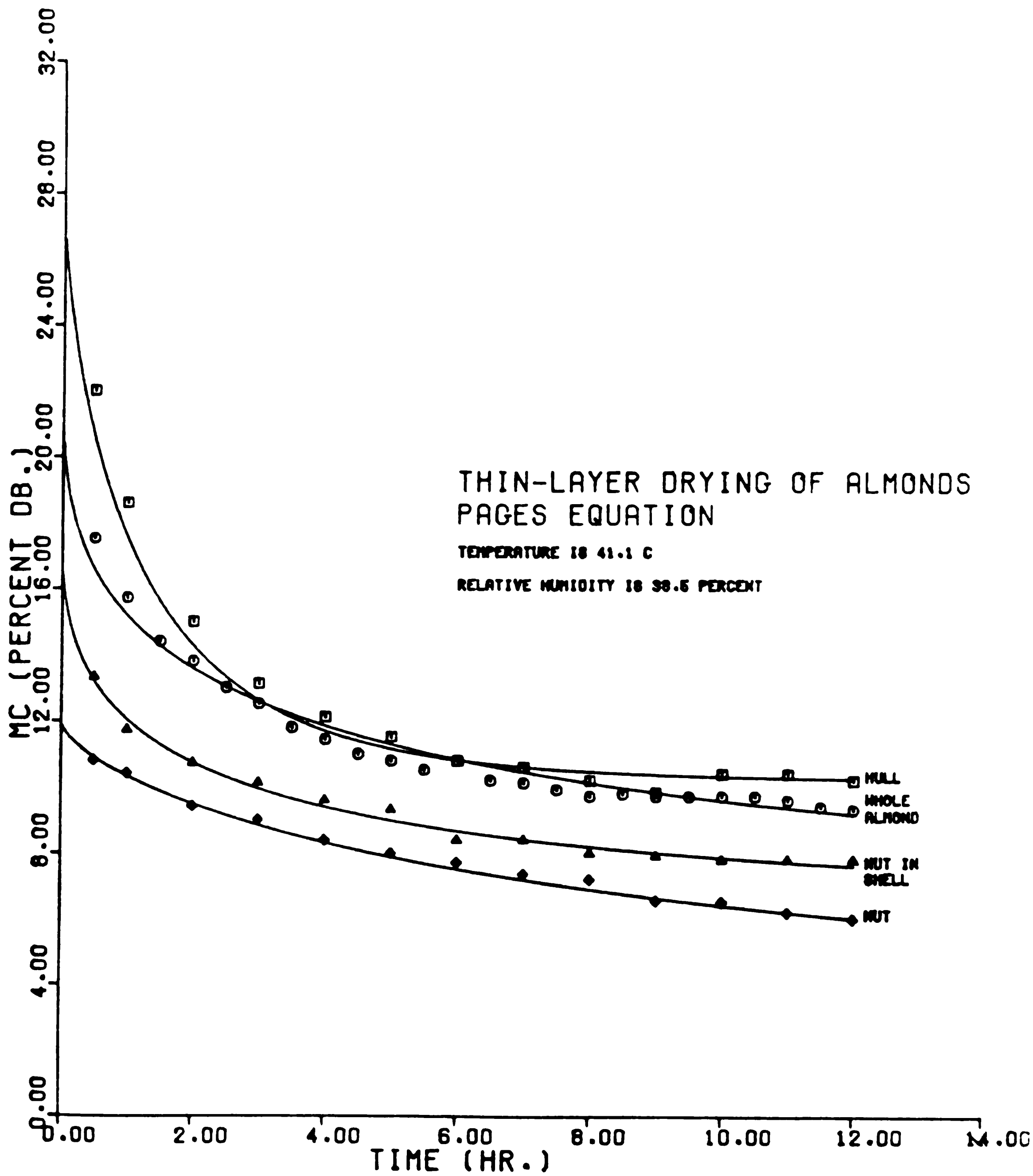

FIGURE 11: Predicted and experimental drying curves of tests 3A, 6A, 7A and 8A using the Page equation with constants as given in Table 6.2.

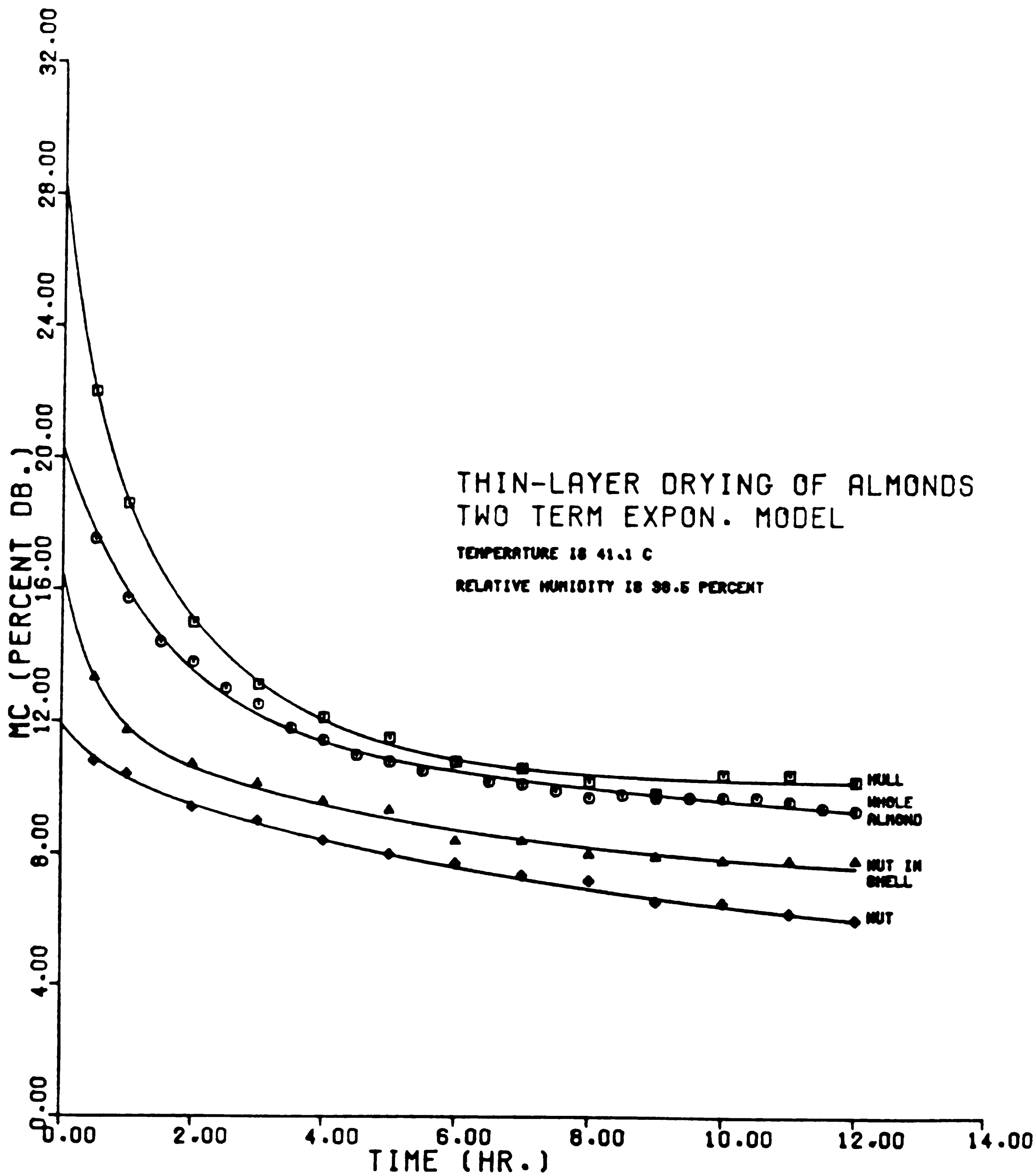

FIGURE 12: Predicted and experimental drying curves of tests 3A, 6A, 7A and 8A using the two term exponential model with constants as given in Table 6.3.

at 45.7°C and 38.5 percent relative humidity,

$$Mt = 0.06606 *\exp(-0.7202*t)+ 0.04918 *\exp(-0.1211*t)+ 0.06517$$

The use of those equations is limited to the temperature range of 41.1°C (106°F) to 45.7°C (114.3°F) and at relative humidity of 38.5 percent. But, the equation is recommended for future modeling studies.

6.2 Deep-Bed Drying Results

The results of three drying tests conducted with the high-temperature crossflow dryer are tabulated in Table 6.4.

The almonds dried to 5-8% moisture content (w.b.) with the high-temperature crossflow dryer were accepted without dockage by the commercial processor (Duche Nut Company, Inc., Orlando, CA). The high drying air temperatures (93.3-98.9°C, 200-210°F) did not affect the nut quality because the color did not appear to have been affected by the high-temperature drying treatment.

It can be seen from the data in Table 6.4 that the initial almond moisture content during the three tests varied from 19.6 to 22.5 percent (w.b.). The hulls were dried on the average from 27 to 12 percent, the shells from 17 to 10 percent, and the nuts from 10.5 to 6.5 percent. In the three tests the moisture decrease was 9-12 percentage points. The dryer capacity varied from 3,093 to 4,306 kg/hr.

TABLE 6.4: High-temperature drying of California almonds in a differential product-speed crossflow dryer.

PARAMETER	TESTC 1	TESTC 2	TESTC 3
VARIETY	NONPAREIL	NONPAREIL	MISSION
Inlet almond temp, °C (F)	21.7 (71)	22.8 (73)	22.8(73)
Almond temp. in tempering hopper, °C (F)	57.2(135)	68.3(155)	51.7(125)
Almond (wet) MC,% w.b.	20.6	19.6	22.5
Almond (dry) MC,% w.b.	10.1	10.9	10.5
Hull (wet) MC,% w.b.	26.1	26.6	28.1
Hull (dry) MC,% w.b.	13.9	14.1	10.8
Shell (wet) MC,% w.b.	16.3	16.4	18.7
Shell (dry) MC,% w.b.	10.8	9.7	9.7
Nut (wet) MC,% w.b.	10.5	8.7	12.4
Nut (dry) MC,% w.b.	6.1	6.5	6.7
Capacity, dry kg/hr(lb/hr)	3,093(6,820)	3,289(6,660)	4,306(8,720)
Fuel consumption kJ/kg(Btu/lb)	8,492(3,651)	9,697(4,167)	5,173(2,224)

The low airflow rate during the TestC 3 contributed to an excellent specific fuel consumption of 2,224 Btu/lb, considerable less than for the first two tests which were conducted at a 25% higher airflow rate.

Almonds dried in a modified crossflow grain dryer required slightly more energy than that experienced with cereal grains (Rodriquez, 1982).

6.2.1 Moisture Content Determination Method

The samples collected during TestC 2 were used to determine the length of oven-time required for the moisture content determination of almonds. Seven samples were collected and divided into wet and dried samples. Table 6.5 shows the results obtained by drying whole almonds for 20,24, 39, 48 and 96 hours in an air-oven at 100^{o}C (212^{o}F).

By plotting moisture content vs. time on linear paper (Figure 13), it can be seen that there is a sudden increase in almond weight loss between 39 and 48 hours. It appears that almonds are loosing products other than water (probably fat). Therefore, almonds must be dried for no larger than 39 hours at 100^{o}C to determine the moisture loss.

Table 6.6 shows data on the relative weights and moisture contents of a sample of Nonpareil almonds before and after drying. The amount of water to be evaporated from each part of the fruit in one ton of wet almonds is also tabulated. Note that over 50 percent of the almond weight consists of hulls regardless of the moisture content. Of the total amount of water to be extracted in the almond drying process, only 12 percent in this particular sample comes from the nuts and almost 75 percent from the hulls.

TABLE 6.5: Calculated moisture content of whole almonds after 20, 24, 39, 48, and 96 hours in an air-oven at 100°C (212°F).

TIME (hr.)	MOISTURE CONTENT (percent d.b.)	
	wet almond	dried almond
20	20.9	12.7
24	21.1	12.9
39	21.4	13.5
48	23.8	16.6
96	27.0	17.7

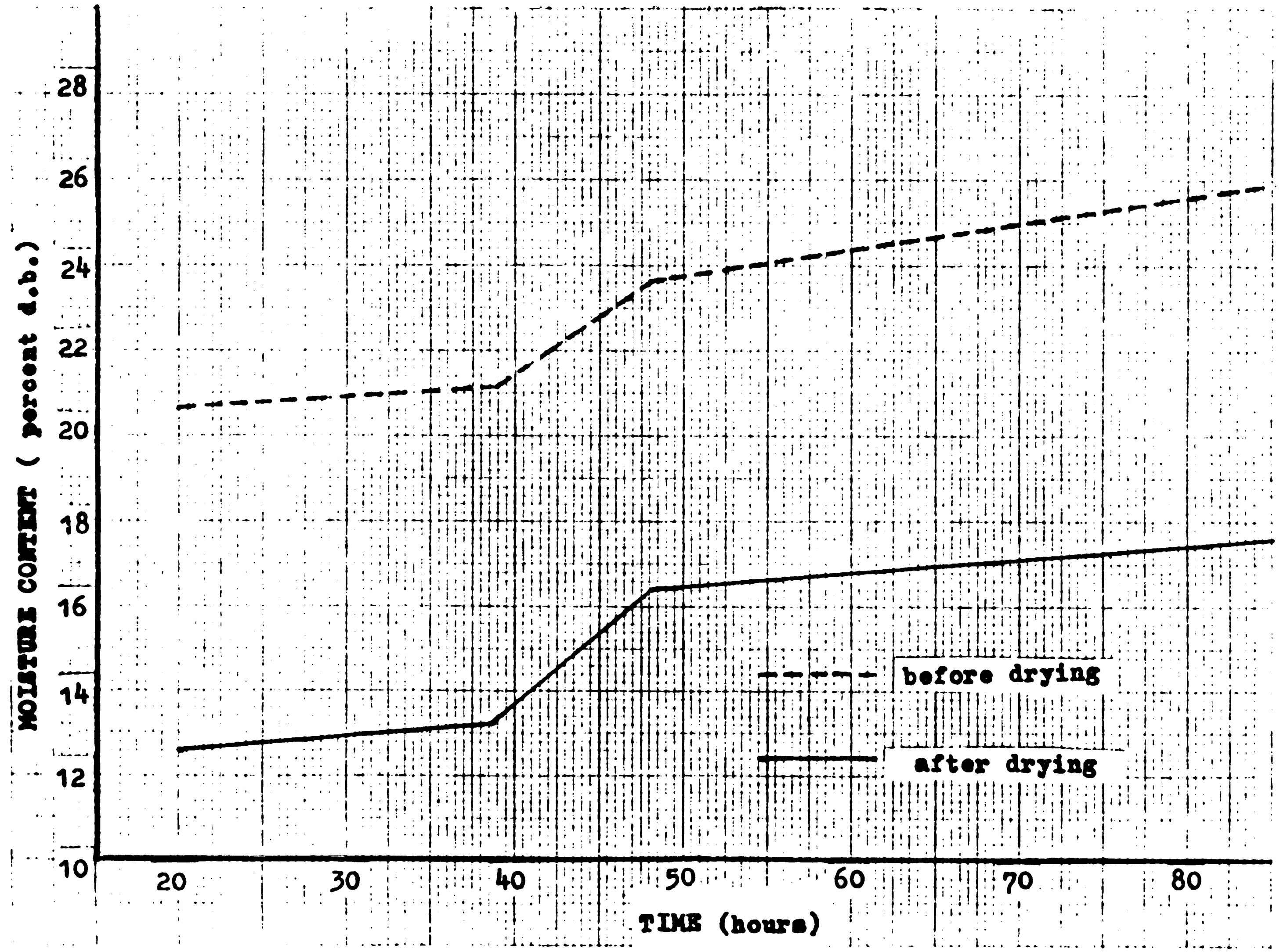

FIGURE 13: Calculated moisture content vs. time for whole almonds subjected to a 100°C environment.

TABLE 6.6: Relative weights, moisture contents and amount of water to be evaporated from one ton of nonpareil almonds.

ALMOND PART	BEFORE DRYING		AFTER DRYING		WATER EVAPORATED PER TON
	Weight (%)	MC (%w.b.)	Weight (%)	MC (%w.b.)	
Hull	52.0	25.0	56.6	13.4	139.3
Shell	17.3	16.4	16.5	9.4	26.7
Nut	30.7	8.7	27.0	5.2	22.7
Whole	100.0	17.7	100.0	10.4	188.7

CHAPTER 7

CONCLUSIONS

The drying of almonds in a thin-layer dryer and in a high-temperature crossflow dryer has been investigated. The main conclusions drawn from this study are:

1. Three models have been investigated for their suitability to describe thin-layer drying of almonds. The two term exponential model was superior to the Page and logarithmic equations in describing the drying behavior of Nonpareil almonds.

2. Almonds have been dried successfully in a high-temperature crossflow dryer; the differential product-speed in the columns and the tempering between drying stages contributed to a high-quality of the final product.

3. In a modified crossflow dryer almonds require slightly more energy for drying than cereal grains.

4. The drying characteristics of individual almond parts have been determined. Hulls contain the most water,

nuts the least; the highest drying rate is exhibited by the hulls, the slowest by the nuts.

5. The correct length of time for the moisture content determination of almonds in a 100°C air oven has been established; 39 hours in an air-oven at 100°C (212°F) is recommended.

CHAPTER 8

SUGGESTION FOR FUTURE STUDY

1. Collection of data over a wider range of temperature and relative humidities should be conducted in order to develop a general model for almond drying.

2. A general thin-layer drying model in the form:

$$M(t) = f(t, T, RH, Mo)$$

should be obtained.

3. The correct length of time for moisture content determination should be determined for each individual almond part. Also, the moisture content determination should be compared with other methods used for almonds.

4. The developed thin-layer almond drying equation should be used in a deep bed analysis to aid dryer manufacturers in designing an optimal almond dryer for on-farm and processing use.

APPENDIX

LISTING OF SELECTED DATA COLLECTED FROM THE THIN-LAYER DRYER

Test 2

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	TEMPERATURE DEG. C	HUMIDITY PERCENT
0	1	18.3	17.9	46.0	37.1
0	14	17.1	16.4	46.2	36.8
0	24	16.5	15.7	46.2	36.9
0	34	15.8	15.0	46.1	36.9
0	44	15.1	14.4	46.2	36.8
0	54	14.7	14.0	46.2	36.8
1	4	14.2	13.5	46.0	36.9
1	14	13.9	13.2	46.0	36.8
1	24	13.3	12.6	46.0	37.1
1	34	13.1	12.4	46.0	37.1
1	44	12.9	12.1	45.9	37.1
1	54	12.6	11.9	46.0	37.1
2	4	12.3	11.3	45.9	37.3
2	14	11.9	11.2	45.9	37.3
2	24	11.9	11.2	45.8	37.3
2	34	11.5	10.7	45.9	37.1
2	44	11.5	10.7	45.8	37.4
2	54	11.3	10.5	45.9	37.4
3	4	11.2	10.3	45.8	37.4
3	14	11.1	10.2	45.8	37.3
3	24	10.9	10.0	45.9	37.3
3	34	10.8	9.9	45.8	37.3
3	44	10.7	9.8	45.8	37.2
3	54	10.6	9.6	45.9	37.2
4	4	10.5	9.6	45.9	37.2
4	14	10.3	9.4	45.8	37.3
4	24	10.4	9.4	45.9	37.0
4	34	10.2	9.1	45.9	37.0
4	44	10.1	9.1	45.9	37.5
4	54	10.0	9.2	45.8	37.5
5	4	10.0	8.8	45.9	37.3
5	13	9.8	8.8	45.8	37.4
5	23	9.8	8.8	45.8	37.2
5	34	9.8	8.7	45.8	37.5
5	43	9.8	8.5	45.9	37.3
5	53	9.5	8.5	45.8	37.5
6	3	9.6	8.3	45.7	37.6
6	13	9.5	8.3	45.7	37.7
6	23	9.5	8.3	45.8	37.4
6	33	9.3	8.2	45.7	37.6
6	43	9.3	8.1	45.6	37.6
6	53	9.4	8.1	45.6	37.8
7	3	9.3	8.0	45.7	37.6

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
7	13	9.2	8.1	45.7	37.6
7	23	9.1	8.0	45.6	37.7
7	33	9.2	8.0	45.6	37.8
7	43	9.1	7.9	45.6	37.8
7	53	8.9	7.8	45.6	37.7
8	3	8.9	7.9	45.6	37.9
8	13	8.8	7.6	45.6	37.9
8	23	8.9	7.5	45.6	37.9
8	33	8.8	7.5	45.6	37.7
8	43	8.8	7.7	45.6	37.6
8	53	8.8	7.5	45.5	37.8
9	3	8.8	7.4	45.5	37.9
9	13	8.8	7.5	45.5	37.8
9	23	8.7	7.5	45.5	37.9
9	33	8.7	7.4	45.4	37.9
9	43	8.7	7.4	45.5	37.8
9	53	8.6	7.4	45.5	38.1
10	3	8.7	7.2	45.5	37.9
10	13	8.4	7.0	45.5	38.0
10	23	8.3	7.3	45.4	38.1
10	33	8.4	7.2	45.4	38.1
10	43	8.4	7.0	45.4	38.2
10	53	8.3	7.1	45.4	38.2
11	3	8.3	7.0	45.4	38.3
11	13	8.4	7.1	45.4	38.0
11	23	8.2	6.9	45.4	38.0
11	33	8.3	7.0	45.4	38.3
11	43	8.3	6.9	45.5	37.8
11	53	8.3	6.9	45.5	37.8
12	3	8.1	6.9	45.5	37.9
12	13	8.2	6.8	45.5	38.1
12	23	8.2	6.8	45.5	37.9
12	33	8.3	6.7	45.4	38.2
12	43	8.1	6.9	45.6	37.8
12	52	8.1	6.8	45.5	38.0
13	2	8.1	6.7	45.5	37.7
13	12	8.1	6.8	45.5	37.8
13	22	8.1	6.6	45.5	37.9
13	32	7.8	6.7	45.5	38.0
13	42	8.1	6.6	45.5	37.9
13	52	7.9	6.6	45.5	38.1
14	2	7.9	6.5	44.9	39.2
14	12	8.0	6.5	45.4	38.2

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	TEMPERATURE DEG. C	RELATIVE HUMIDITY PERCENT
14	22	8.1	6.5	45.6	37.7
14	32	8.0	6.6	45.6	37.8
14	42	7.9	6.7	45.7	37.3
14	52	7.8	6.6	45.6	37.7
15	2	7.9	6.5	45.6	37.7
15	12	7.7	6.4	45.6	37.7
15	22	7.9	6.5	45.6	37.7
15	32	7.8	6.5	45.6	37.7
15	42	7.6	6.4	45.8	37.6
15	52	7.8	6.4	45.6	37.6
16	2	7.8	6.5	45.8	37.4
16	12	7.8	6.3	45.7	37.7
16	22	7.7	6.3	45.7	37.7
16	32	7.9	6.5	45.8	37.6
16	42	7.7	6.3	45.7	37.6
16	52	7.7	6.3	45.9	37.4
17	2	7.7	6.5	45.8	37.5
17	12	7.7	6.5	45.8	37.4
17	22	7.8	6.6	45.9	37.2
17	32	7.8	6.5	45.9	37.3
17	42	7.7	6.5	45.8	37.3
17	52	7.7	6.6	45.9	37.3
18	2	7.7	6.6	46.0	37.1
18	12	7.7	6.7	46.0	37.0
18	22	7.8	6.6	46.0	37.0
18	32	7.6	6.6	46.1	37.0
18	42	7.7	6.6	46.0	36.9
19	12	7.6	6.6	46.2	36.8
19	42	7.7	6.6	46.3	36.8
20	12	7.7	6.5	46.3	36.6
20	42	7.6	6.6	46.3	36.7
21	12	7.6	6.8	46.4	36.6
21	42	7.5	6.7	46.0	37.0
22	12	7.5	6.7	46.3	36.6
22	42	7.5	6.7	46.5	36.3
23	12	7.3	6.8	46.5	36.2
23	42	7.3	6.7	46.5	36.2
24	12	7.1	6.6	46.5	36.2
24	42	7.1	6.5	46.4	36.5
25	12	7.2	6.6	46.4	36.4
25	42	7.1	6.4	46.3	36.4
26	12	6.8	6.2	46.3	36.5
26	42	7.2	6.6	46.2	36.8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
27	12	7.3	6.5	46.3	36.6
27	42	7.0	6.5	46.2	36.7
28	12	7.0	6.3	46.3	36.5
28	42	7.2	6.5	46.3	36.6
29	12	6.7	6.1	46.1	36.8
29	42	6.9	6.3	46.1	36.8
30	12	6.8	6.3	46.0	37.0
30	42	6.9	6.2	46.1	36.7
31	12	6.8	6.2	46.1	36.8
31	42	7.0	6.4	46.0	37.0
32	12	6.8	6.6	46.0	37.1
32	42	6.8	6.3	46.0	37.0
33	11	6.8	6.5	45.9	37.5
33	41	6.9	6.0	45.9	37.3
34	11	6.7	6.3	45.9	37.0
34	41	6.9	6.1	46.1	36.8
35	11	6.9	6.3	46.0	37.0
35	41	6.9	6.2	45.9	37.0
36	11	6.8	6.1	46.0	36.8
36	41	6.8	6.3	45.9	37.2
37	11	6.8	6.2	46.1	37.0
37	41	6.9	6.2	45.9	37.1
38	11	6.8	6.2	45.9	37.3
38	41	6.8	6.1	45.9	37.3
39	11	6.8	6.1	45.9	37.0
39	41	7.0	6.0	45.9	37.3
40	11	6.9	6.0	45.9	37.0
40	41	6.8	6.0	46.0	36.8
41	11	7.2	6.0	46.1	36.9
41	41	6.9	6.2	46.0	36.8
42	11	6.9	6.2	46.2	36.8

Test 3

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
0	1	20.4	19.5	40.6	38.9
0	31	17.5	17.1	41.3	38.0
1	0	15.7	15.4	41.3	38.1
1	30	14.4	14.2	41.4	37.7
2	0	13.8	13.4	41.5	37.5
2	30	13.0	12.8	41.6	37.6
3	0	12.5	12.2	41.6	37.6
3	30	11.8	11.8	41.4	37.8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
4	1	11.3	11.5	41.4	37.9
4	31	11.0	11.1	41.4	37.9
5	1	10.8	10.9	41.3	38.0
5	31	10.5	10.5	41.4	37.9
6	1	10.5	10.3	41.3	38.0
6	31	10.2	10.1	41.5	37.8
7	1	10.1	9.9	41.4	37.9
7	31	9.9	9.9	41.4	37.9
8	1	9.7	9.2	41.3	38.3
8	31	9.8	9.2	41.2	38.2
9	1	9.7	9.7	41.2	38.3
9	30	9.7	9.7	41.3	38.2
10	0	9.7	9.6	41.3	38.2
10	30	9.7	9.6	41.3	38.0
11	0	9.6	9.5	41.3	38.0
11	31	9.4	9.4	41.3	38.2
12	1	9.3	9.3	40.9	38.4
12	31	9.3	9.3	40.9	38.7
13	1	9.1	9.2	40.9	38.5
13	30	9.2	9.1	40.8	38.7
14	0	9.1	9.0	40.8	38.8
14	30	9.0	8.9	40.8	38.8
15	0	9.0	8.7	40.8	38.8
15	30	8.9	8.7	40.8	39.0
16	1	8.9	8.6	40.7	39.1
16	31	8.6	8.6	40.7	39.1
17	1	8.6	8.6	40.8	38.8
17	31	8.7	8.5	40.7	38.8
18	1	8.7	8.4	40.8	38.8
18	31	8.4	8.4	40.9	38.7
19	1	8.4	8.4	41.0	38.4
19	31	8.3	8.1	41.0	38.3
20	0	8.4	8.3	41.0	38.1
20	30	8.2	8.3	41.1	38.2
21	0	8.2	8.2	41.1	38.2
21	30	8.2	8.0	41.2	38.0
22	0	8.2	8.2	41.2	37.8
22	30	8.2	8.1	41.2	38.0
23	1	8.1	8.0	40.6	39.1
23	31	8.1	8.1	41.2	38.0
24	0	7.9	8.0	41.4	37.7

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
24	30	7.9	7.9	41.5	37.5
25	0	7.8	7.9	41.4	37.6
25	30	7.7	7.8	41.5	37.5
26	1	7.7	7.8	41.5	37.4
26	30	7.5	7.8	41.5	37.4
27	1	7.4	7.6	41.4	37.5
27	30	7.5	7.5	41.3	37.7
28	1	7.5	7.6	41.1	38.1
28	30	7.5	7.7	41.1	38.1
29	0	7.3	7.6	41.1	38.2
29	30	7.4	7.6	41.3	38.1
30	0	7.4	7.5	41.2	38.0
30	30	7.3	7.4	41.2	38.1
31	0	7.3	7.3	41.2	38.1
31	30	7.2	7.2	41.0	38.3
32	1	7.2	7.2	41.0	38.5
32	30	7.2	7.2	40.9	38.4
33	1	7.1	7.1	40.9	38.6
33	30	7.0	7.1	40.9	38.5
34	0	6.9	7.0	40.8	38.7
34	30	7.0	7.0	40.8	38.6
35	0	7.0	7.0	40.8	38.6
35	30	7.0	6.9	40.8	38.7
36	1	6.9	6.9	40.8	38.7
36	30	7.1	6.9	40.8	38.7
37	1	6.9	7.0	40.7	38.8
37	30	6.9	6.9	40.8	38.7
38	0	6.9	6.9	40.8	38.9
38	30	7.0	6.8	40.7	38.9
39	1	6.8	6.8	40.8	38.7
39	30	6.9	6.8	40.8	38.7
40	1	6.9	6.7	40.8	38.7
40	30	6.8	6.7	40.8	38.6
41	0	6.9	6.8	40.7	38.9
41	30	6.9	6.8	40.8	38.8
42	0	7.1	6.8	41.0	38.4
42	30	7.0	6.9	41.0	38.3
43	0	7.0	6.8	41.0	38.3
43	30	7.0	6.8	41.1	38.1
44	0	7.0	6.7	41.0	38.3

Test 6

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
0	1	16.4	15.8	41.1	40.0
0	10	15.1	14.6	41.3	39.8
0	20	14.2	13.6	41.1	40.0
0	30	13.3	13.0	41.2	39.8
0	40	12.7	12.4	41.2	39.9
0	50	12.4	11.9	41.2	39.8
1	0	11.7	11.4	41.2	39.9
1	10	11.4	11.0	41.1	40.0
1	20	11.2	10.8	41.3	40.0
1	30	10.9	10.6	41.1	40.0
1	41	10.6	10.4	41.1	40.2
1	51	10.4	10.2	41.1	40.0
2	1	10.7	10.1	41.2	39.9
2	11	10.7	10.1	41.3	39.9
2	21	10.4	10.0	41.3	39.9
2	38	10.4	9.9	41.2	39.8
2	48	10.2	9.8	41.3	39.9
2	57	10.1	9.7	41.3	39.5
3	7	10.1	9.7	41.3	39.6
3	17	9.9	9.5	41.1	40.0
3	27	9.9	9.4	41.3	39.7
3	37	9.8	9.3	41.3	39.7
3	47	9.7	9.4	41.1	40.0
3	57	9.6	9.3	41.1	40.0
4	7	9.6	9.2	41.2	39.8
4	17	9.5	9.2	41.2	39.8
4	27	9.4	9.1	41.3	39.6
4	37	9.4	9.0	41.1	39.8
4	47	9.3	9.0	41.3	39.8
4	57	9.3	9.0	41.2	39.8
5	7	9.2	8.8	41.2	39.8
5	17	9.0	8.6	41.1	39.8
5	27	8.7	8.4	41.1	40.1
5	37	8.7	8.3	41.1	40.1
5	47	8.4	8.2	41.0	40.4
5	57	8.4	8.2	41.1	40.1
6	7	8.5	8.1	41.1	40.1
6	17	8.5	8.1	41.1	40.2
6	27	8.4	8.0	41.0	40.3
6	37	8.4	8.0	41.1	40.0
6	46	8.3	7.9	41.0	40.3
6	56	8.3	7.9	41.0	40.2
7	6	8.4	7.8	41.0	40.5

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
7	16	8.1	7.8	41.0	40.5
7	26	8.2	7.7	41.0	40.4
7	36	8.2	7.6	41.0	40.3
7	46	8.2	7.6	41.0	40.4
7	56	8.1	7.7	40.9	40.6
8	6	7.9	7.5	41.0	40.5
8	16	7.9	7.4	40.9	40.7
8	26	7.9	7.4	40.9	40.5
8	36	7.9	7.4	40.8	40.9
8	46	7.9	7.3	40.9	40.7
8	56	7.9	7.3	40.9	40.7
9	6	7.8	7.3	40.8	41.0
9	16	8.0	7.3	40.8	40.8
9	26	8.0	7.3	40.8	40.7
9	36	7.9	7.3	40.9	40.7
9	46	8.0	7.3	40.9	40.7
9	56	7.9	7.2	40.8	40.7
10	5	7.8	7.3	40.9	40.6
10	15	7.8	7.2	40.8	40.5
10	25	7.8	7.3	40.8	40.5
10	35	7.9	7.3	40.8	40.7
10	45	7.9	7.4	40.8	40.8
10	55	7.8	7.2	40.8	40.7
11	5	7.8	7.3	40.8	40.8
11	15	7.8	7.3	40.8	41.0
11	25	7.9	7.4	40.8	41.0
11	35	7.9	7.5	40.8	40.8
11	45	7.9	7.5	40.8	40.8
11	55	7.9	7.5	40.9	40.5
12	5	7.8	7.5	40.8	40.5
12	15	7.8	7.4	40.9	40.7
12	25	7.9	7.5	40.8	40.6
12	35	7.8	7.4	40.9	40.5
12	45	7.6	7.2	41.0	40.5
12	55	7.4	7.2	40.9	40.5
13	5	7.4	7.1	40.9	40.7
13	15	7.4	7.0	40.9	40.6
13	25	7.4	7.0	40.9	40.7
13	35	7.3	6.9	40.9	40.7
13	45	7.4	6.9	40.9	40.7
13	55	7.2	7.0	40.8	40.9
14	5	7.1	6.9	40.8	40.9
14	15	7.2	6.8	40.8	40.8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
14	25	7.3	6.9	40.8	40.8
14	35	7.5	7.1	40.9	40.6
14	44	7.5	7.1	41.0	40.0
14	54	7.5	7.1	41.1	40.2
15	4	7.5	7.1	41.0	40.0
15	14	7.4	7.1	41.0	40.2
15	24	7.5	7.1	41.1	40.2
15	34	7.4	7.1	41.1	40.2
15	44	7.5	7.1	41.1	40.1
15	54	7.4	7.0	41.1	40.2
16	4	7.3	7.1	41.1	39.9
16	14	7.4	7.0	41.1	40.1
16	24	7.4	7.0	41.1	40.2
16	34	7.3	7.0	41.1	40.2
16	44	7.3	6.9	41.1	40.2
16	54	7.3	6.9	41.1	40.1
17	4	7.3	6.9	41.1	40.1
17	14	7.2	6.8	41.0	40.2
17	24	7.3	6.8	41.1	40.1
17	34	7.2	6.8	41.1	40.1
17	44	7.1	6.8	41.1	40.1
17	54	7.1	6.7	41.1	40.1
18	4	7.1	6.8	41.0	40.2
18	14	7.1	6.8	41.0	40.2
18	24	7.1	6.8	41.1	40.2
18	34	7.2	6.8	41.1	40.1
18	44	7.1	6.7	41.1	40.1
18	54	7.1	6.7	41.0	40.2
19	4	7.1	6.7	41.1	39.9
19	14	7.1	6.7	41.0	40.2
19	24	7.0	6.7	41.0	40.2
19	34	7.1	6.7	41.0	40.2
19	44	7.0	6.6	41.0	40.2
19	54	7.0	6.7	41.1	40.1
20	4	7.0	6.7	41.0	40.1
20	14	7.0	6.7	41.1	40.0
20	23	7.0	6.6	41.3	39.8
20	33	7.0	6.5	41.3	39.9
20	43	7.0	6.6	41.3	39.7
20	53	7.0	6.5	41.3	39.7
21	3	6.9	6.4	41.3	39.6
21	13	7.0	6.7	41.4	39.2
21	23	7.0	6.7	41.4	39.3

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
21	33	7.1	6.7	41.4	39.3
21	43	6.9	6.5	41.4	39.0
21	53	7.0	6.5	41.5	39.0
22	3	6.8	6.6	41.5	39.1
22	13	6.8	6.5	41.3	39.1

<u>Test 7</u>

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
0	1	28.3	26.8	41.4	39.3
0	2	27.8	26.4	41.5	38.8
0	3	27.5	26.3	41.5	39.0
0	4	27.3	26.0	41.5	38.9
0	4	26.9	25.7	41.6	38.9
0	5	26.7	25.3	41.6	38.8
0	6	26.5	25.1	41.6	38.7
0	7	26.3	24.8	41.5	38.7
0	8	26.1	24.5	41.5	38.8
0	9	25.9	24.4	41.5	38.9
0	10	25.5	24.1	41.4	39.0
0	11	25.3	23.9	41.5	39.0
0	12	25.1	23.7	41.5	39.0
0	13	24.7	23.5	41.4	38.9
0	14	24.6	23.3	41.6	38.9
0	15	24.4	23.1	41.6	38.6
0	16	24.3	22.9	41.5	38.6
0	17	24.1	22.7	41.6	38.9
0	18	24.1	22.5	41.6	38.6
0	19	23.7	22.3	41.4	38.5
0	20	23.4	22.0	41.4	39.2
0	21	23.4	21.9	41.4	39.2
0	22	23.3	21.5	41.5	38.8
0	23	23.1	21.5	41.5	38.7
0	24	22.7	21.2	41.6	38.8
0	25	22.5	21.1	41.6	38.8
0	26	22.4	20.9	41.5	38.8
0	27	22.1	20.8	41.6	38.8
0	28	22.1	20.7	41.6	38.8
0	29	21.9	20.5	41.6	38.9
0	30	22.0	20.5	41.7	38.8
0	31	21.8	20.3	41.7	38.4
0	32	21.5	20.2	41.6	38.4
0	33	21.4	20.2	41.9	38.6
0	34	21.4	20.0	41.8	38.3

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
0	35	21.3	19.9	41.8	38.3
0	36	21.1	19.8	41.8	38.5
0	37	20.9	19.8	41.6	38.5
0	38	20.7	19.6	41.7	38.6
0	39	20.6	19.4	41.6	38.5
0	40	20.6	19.3	41.7	38.5
0	41	20.4	19.1	41.7	38.5
0	42	20.2	19.1	41.8	38.4
0	43	20.3	19.0	41.7	38.4
0	44	20.2	18.8	41.8	38.5
0	45	20.0	18.8	41.8	38.5
0	46	20.0	18.8	41.8	38.3
0	47	19.8	18.6	41.8	38.4
0	48	19.8	18.5	41.7	38.5
0	49	19.6	18.4	41.6	38.5
0	50	19.6	18.3	41.7	38.5
0	51	19.5	18.2	41.6	38.6
0	52	19.4	18.1	41.8	38.4
0	53	19.2	18.1	41.8	38.2
0	54	19.1	18.2	41.8	38.3
0	55	19.1	18.0	41.8	38.3
0	56	19.0	17.9	41.8	38.2
0	57	18.8	17.6	41.8	38.3
0	58	18.6	17.6	41.8	38.3
0	59	18.8	17.6	41.8	38.4
1	0	18.6	17.5	41.8	38.2
1	1	18.4	17.5	41.8	38.2
1	2	18.3	17.5	41.9	38.1
1	3	18.3	17.3	41.9	38.2
1	4	18.3	17.2	41.9	38.2
1	5	18.2	17.1	41.8	38.3
1	6	18.0	17.1	41.8	38.2
1	7	17.9	17.0	41.8	38.0
1	8	18.0	17.0	41.9	38.0
1	9	17.8	16.9	41.9	38.2
1	10	17.8	16.8	41.9	38.1
1	11	17.8	16.7	41.8	38.1
1	20	17.2	16.2	41.8	38.5
1	30	16.6	15.6	41.7	38.7
1	40	15.9	14.9	41.5	38.7
1	50	15.4	14.3	41.5	39.0
2	0	15.0	14.2	41.6	38.9
2	10	14.6	13.7	41.6	38.8
2	20	14.3	13.5	41.6	38.7
2	30	14.1	13.2	41.6	38.8
2	40	13.8	13.0	41.6	38.8
2	50	13.5	12.9	41.6	38.7
3	0	13.1	12.6	41.8	38.5
3	10	12.9	12.5	41.8	38.6
3	19	12.8	12.3	41.8	38.6
3	29	12.5	12.1	41.7	38.8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
3	39	12.5	12.0	41.8	38.8
3	49	12.3	12.0	41.8	38.7
3	59	12.2	11.9	41.8	38.5
4	9	12.1	11.8	41.8	38.5
4	19	11.8	11.6	41.8	38.4
4	29	11.7	11.5	41.8	38.4
4	39	11.6	11.5	41.8	38.5
4	49	11.4	11.5	41.8	38.4
4	59	11.5	11.3	41.8	38.6
5	9	11.4	11.2	41.5	38.7
5	19	11.1	11.0	41.5	38.9
5	29	11.0	10.8	41.5	38.9
5	38	10.9	10.8	41.5	38.8
5	48	10.9	10.5	41.4	39.2
5	58	10.8	10.5	41.4	39.2
6	8	10.7	10.4	41.4	39.3
6	18	10.8	10.5	41.4	39.2
6	28	10.8	10.5	41.4	39.0
6	38	10.6	10.5	41.5	39.0
6	48	10.6	10.6	41.5	39.2
6	58	10.6	10.7	41.3	39.2
7	8	10.6	10.7	41.5	39.0
7	18	10.5	10.7	41.4	39.0
7	28	10.7	10.6	41.4	38.9
7	38	10.4	10.6	41.4	39.1
7	48	10.4	10.7	41.4	39.0
7	58	10.3	10.5	41.5	39.1
8	8	10.1	10.3	41.4	39.2
8	18	10.4	10.3	41.4	39.2
8	28	10.3	10.3	41.3	39.2
8	38	10.2	10.1	41.3	39.2
8	48	10.0	10.1	41.2	39.6
8	58	9.9	10.1	41.3	39.5
9	7	9.9	9.8	41.1	39.7
9	17	10.2	10.1	41.1	39.8
9	27	10.3	9.7	41.2	39.8
9	37	10.5	10.4	41.3	39.6
9	47	10.4	10.3	41.5	39.2
9	57	10.5	10.5	41.6	38.9
10	7	10.3	10.6	41.6	38.6
10	17	10.5	10.6	41.7	38.7
10	27	10.4	10.6	41.6	38.5
10	37	10.3	10.5	41.7	38.5

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
10	47	10.4	10.6	41.7	38.4
10	57	10.4	10.6	41.6	38.6
11	7	10.4	10.7	41.6	38.5
11	17	10.4	10.6	41.7	38.5
11	27	10.2	10.6	41.5	38.7
11	37	10.3	10.5	41.7	38.5
11	47	10.3	10.5	41.6	38.6
11	57	10.3	10.5	41.6	38.5
12	7	10.1	10.5	41.6	38.7
12	17	10.0	10.5	41.6	38.8
12	27	10.1	10.4	41.6	38.5
12	37	10.1	10.5	41.6	38.7
12	46	10.1	10.4	41.5	38.7
12	56	10.0	10.3	41.8	38.4
13	6	10.0	10.3	41.7	38.4
13	16	10.0	10.2	41.7	38.5
13	26	10.0	10.2	41.7	38.5
13	36	10.1	10.2	41.6	38.7
13	46	10.0	10.3	41.6	38.7
13	56	10.2	10.3	41.7	38.6
14	6	9.9	10.2	41.6	38.8
14	16	10.0	10.2	41.6	38.7
14	26	9.7	10.1	41.4	39.0
14	36	9.9	10.1	41.5	38.9
14	46	10.0	10.2	41.5	38.9
14	56	10.0	10.2	41.5	39.0
15	6	9.9	10.2	41.5	38.9
15	16	10.0	10.2	41.6	38.9
15	26	10.1	10.3	41.5	38.8
15	36	9.9	10.2	41.6	38.6
15	45	10.0	10.2	41.6	38.6
15	55	10.1	10.2	41.6	38.6
16	5	10.0	10.3	41.5	38.7
16	15	10.2	10.3	41.6	38.8
16	25	10.2	10.2	41.6	38.7
16	35	10.0	10.2	41.6	38.7
16	45	10.1	10.2	41.7	38.4
16	55	10.1	10.2	41.6	38.5
17	5	10.1	10.2	41.6	38.5
17	15	10.0	10.2	41.6	38.5
17	25	10.0	10.2	41.6	38.5
17	35	10.1	10.2	41.6	38.7
17	45	10.1	10.2	41.7	38.8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
		SAMPLE A	SAMPLE B		
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
17	55	10.1	10.1	41.6	38.5
18	5	10.0	10.2	41.6	38.6
18	15	10.2	10.1	41.7	38.8
18	25	10.2	10.2	41.6	38.6
18	35	10.2	10.1	41.7	38.5
18	45	10.1	10.1	41.7	38.6
18	55	10.0	10.1	41.6	38.6
19	5	10.1	10.1	41.6	38.5
19	15	10.0	10.2	41.6	38.5
19	25	10.1	10.2	41.6	38.6
19	35	10.2	10.2	41.6	38.7
19	45	10.1	10.1	41.5	38.7
19	55	10.1	10.2	41.6	38.9
20	4	10.2	10.1	41.6	38.8
20	14	10.1	10.1	41.4	39.1
20	24	10.1	10.3	41.3	39.2
20	34	10.2	10.3	41.2	39.2
20	44	10.2	10.1	41.1	39.8
20	54	10.0	10.1	41.0	39.7
21	4	10.1	10.1	41.1	39.9
21	14	10.4	10.2	41.2	39.9
21	24	10.5	10.3	41.3	39.4
21	34	10.4	10.2	41.1	39.6
21	44	10.4	10.4	41.1	39.8
21	54	10.4	10.0	41.0	40.0
22	4	10.5	10.1	41.0	40.1
22	14	10.4	10.1	41.0	40.0
22	24	10.6	10.3	41.1	39.9
22	34	10.4	10.2	41.1	39.9
22	44	10.5	10.1	41.1	40.0
22	54	10.5	10.0	41.1	39.9
23	4	10.5	10.0	41.0	40.1
23	14	10.5	10.1	41.0	40.1
23	24	10.3	9.9	41.1	40.0
23	34	10.2	10.1	41.0	40.1
23	44	10.4	10.1	41.0	40.3

Test 8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
0	1	11.9	12.3	41.3	39.7
0	1	11.9	12.2	41.4	39.5
0	2	11.8	12.2	41.4	39.4
0	3	11.7	12.1	41.4	39.4
0	4	11.6	12.0	41.4	39.1
0	5	11.7	12.0	41.5	39.3
0	6	11.6	12.0	41.5	39.0
0	7	11.6	11.9	41.5	39.1
0	8	11.5	11.9	41.4	39.1
0	9	11.4	11.9	41.3	39.2
0	10	11.3	11.7	41.4	39.4
0	11	11.2	11.7	41.3	39.1
0	12	11.2	11.7	41.3	39.1
0	13	11.2	11.7	41.4	39.3
0	14	11.3	11.7	41.4	39.3
0	15	11.2	11.5	41.4	39.1
0	16	11.2	11.5	41.5	39.1
0	17	11.2	11.5	41.5	39.2
0	18	11.2	11.5	41.5	39.0
0	19	11.1	11.5	41.6	39.0
0	20	11.1	11.4	41.5	39.0
0	21	11.1	11.5	41.5	39.1
0	22	11.0	11.5	41.5	39.3
0	23	11.0	11.4	41.5	39.1
0	24	11.0	11.4	41.5	38.9
0	25	11.0	11.5	41.5	39.2
0	26	10.9	11.4	41.5	39.3
0	27	10.9	11.3	41.5	39.1
0	28	10.8	11.3	41.5	39.0
0	29	10.8	11.4	41.5	39.1
0	30	10.8	11.3	41.5	38.7
0	31	10.8	11.3	41.4	39.1
0	32	10.8	11.4	41.4	39.2
0	33	10.8	11.4	41.4	39.2
0	34	10.8	11.3	41.4	39.1
0	35	10.7	11.3	41.4	39.1
0	36	10.7	11.2	41.4	39.2
0	37	10.8	11.3	41.5	38.9
0	38	10.8	11.2	41.5	39.1
0	39	10.7	11.1	41.5	39.0
0	40	10.6	11.2	41.5	39.0
0	41	10.6	11.2	41.4	39.0
0	42	10.7	11.1	41.4	39.2

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	TEMPERATURE DEG. C	HUMIDITY PERCENT
0	43	10.6	11.0	41.4	39.0
0	44	10.5	11.0	41.4	38.9
0	45	10.5	11.0	41.4	39.3
0	46	10.5	11.1	41.4	39.2
0	47	10.5	11.0	41.3	39.1
0	48	10.5	10.9	41.4	39.3
0	49	10.5	10.9	41.4	39.1
0	50	10.4	11.0	41.5	39.0
0	51	10.5	10.9	41.5	38.9
0	52	10.6	11.0	41.6	38.8
0	53	10.6	11.1	41.6	38.9
0	54	10.5	11.1	41.5	38.9
0	55	10.4	11.0	41.5	39.0
0	56	10.5	11.0	41.5	39.1
0	57	10.4	10.9	41.5	39.0
0	58	10.3	11.0	41.5	38.8
0	59	10.3	10.9	41.6	38.8
1	0	10.4	10.9	41.6	38.7
1	1	10.4	10.9	41.5	38.9
1	2	10.3	10.9	41.6	38.9
1	3	10.3	10.8	41.5	38.9
1	4	10.2	10.8	41.5	38.8
1	5	10.1	10.8	41.5	38.6
1	6	10.2	10.8	41.5	39.1
1	7	10.1	10.8	41.5	38.6
1	8	10.1	10.7	41.5	38.6
1	9	10.1	10.8	41.5	39.1
1	10	10.2	10.7	41.5	38.8
1	11	10.1	10.7	41.6	38.8
1	12	10.1	10.6	41.6	38.8
1	13	10.1	10.7	41.6	38.6
1	14	10.1	10.7	41.6	38.8
1	15	10.0	10.6	41.6	38.8
1	16	10.1	10.6	41.6	38.9
1	17	10.1	10.6	41.6	38.8
1	18	10.0	10.5	41.6	38.7
1	19	9.9	10.6	41.6	38.6
1	21	9.9	10.6	41.6	38.8
1	22	10.0	10.6	41.6	38.7
1	23	10.0	10.5	41.5	38.8
1	24	10.0	10.6	41.5	38.9
1	25	10.0	10.4	41.5	38.8
1	26	9.9	10.5	41.5	38.8

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	TEMPERATURE DEG. C	RELATIVE HUMIDITY PERCENT
1	27	9.9	10.5	41.5	39.0
1	28	9.8	10.4	41.5	39.0
1	29	9.9	10.4	41.5	38.6
1	30	9.8	10.4	41.6	38.8
1	31	9.8	10.3	41.6	38.8
1	32	9.9	10.4	41.6	38.7
1	33	9.8	10.4	41.6	38.8
1	34	9.8	10.3	41.6	38.8
1	35	9.8	10.3	41.6	38.6
1	36	9.7	10.3	41.6	38.6
1	37	9.8	10.3	41.6	38.7
1	38	9.7	10.3	41.6	38.8
1	39	9.7	10.3	41.6	38.8
1	40	9.8	10.3	41.6	38.6
1	41	9.8	10.2	41.6	38.7
1	42	9.7	10.1	41.6	38.7
1	43	9.7	10.2	41.7	38.6
1	44	9.6	10.3	41.7	38.5
1	45	9.7	10.2	41.7	38.7
1	46	9.6	10.2	41.6	38.5
1	47	9.6	10.1	41.6	38.5
1	48	9.5	10.2	41.6	38.7
1	49	9.5	10.2	41.7	38.6
1	50	9.6	10.1	41.6	38.6
1	51	9.6	10.1	41.6	38.6
1	52	9.5	10.1	41.6	38.4
1	53	9.5	10.1	41.6	38.7
1	54	9.5	10.1	41.6	38.8
1	55	9.5	10.1	41.6	38.7
1	56	9.6	10.1	41.6	38.7
1	57	9.5	10.1	41.6	38.8
1	58	9.4	10.1	41.6	38.6
1	59	9.4	10.1	41.7	38.5
2	0	9.4	10.0	41.7	38.4
2	1	9.5	10.1	41.7	38.6
2	2	9.5	10.0	41.8	38.6
2	3	9.5	10.0	41.7	38.4
2	4	9.3	10.0	41.7	38.6
2	5	9.3	10.0	41.7	38.6
2	6	9.4	9.9	41.7	38.6
2	7	9.3	10.0	41.6	38.5
2	8	9.4	9.9	41.6	38.6
2	9	9.3	9.8	41.6	38.6

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	TEMPERATURE DEG. C	HUMIDITY PERCENT
2	10	9.3	9.9	41.6	38.7
2	11	9.3	9.9	41.6	38.7
2	12	9.4	9.8	41.6	38.5
2	13	9.4	9.8	41.7	38.5
2	14	9.3	9.8	41.7	38.5
2	15	9.3	9.9	41.7	38.4
2	16	9.3	9.9	41.6	38.5
2	17	9.2	9.9	41.6	38.8
2	18	9.3	9.8	41.6	38.4
2	19	9.2	9.8	41.7	38.4
2	20	9.2	9.8	41.6	38.5
2	21	9.2	9.9	41.6	38.7
2	22	9.3	9.8	41.6	38.5
2	23	9.1	9.7	41.6	38.5
2	24	9.0	9.8	41.7	38.4
2	25	9.2	9.8	41.8	38.5
2	26	9.2	9.7	41.7	38.5
2	27	9.2	9.8	41.7	38.5
2	28	9.1	9.7	41.7	38.6
2	29	9.1	9.7	41.7	38.7
2	30	9.1	9.7	41.7	38.4
2	31	9.1	9.7	41.7	38.5
2	32	9.1	9.7	41.7	38.5
2	33	9.0	9.6	41.6	38.5
2	34	9.1	9.7	41.8	38.5
2	35	9.2	9.7	41.9	38.2
2	36	9.2	9.9	41.9	38.0
2	37	9.2	9.8	41.8	38.1
2	38	9.1	9.8	41.8	38.4
2	39	9.2	9.8	41.7	38.4
2	40	9.1	9.7	41.6	38.4
2	41	9.1	9.7	41.7	38.7
2	42	9.2	9.7	41.8	38.3
2	43	9.0	9.6	41.7	38.3
2	44	9.1	9.6	41.8	38.4
2	45	9.1	9.7	41.8	38.2
2	46	9.0	9.7	41.8	38.2
2	47	9.0	9.6	41.7	38.4
2	48	9.0	9.6	41.6	38.5
2	49	9.1	9.6	41.7	38.4
2	50	9.2	9.6	41.7	38.5
2	51	9.0	9.4	41.7	38.5
2	52	8.9	9.5	41.7	38.5

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT		TEMPERATURE	RELATIVE HUMIDITY
HOURS	MINUTES	SAMPLE A DRY BASIS	SAMPLE B DRY BASIS	DEG. C	PERCENT
2	53	9.0	9.4	41.6	38.5
2	54	9.0	9.4	41.6	38.5
2	55	9.1	9.3	41.7	38.6
2	56	9.0	9.3	41.7	38.4
2	57	8.9	9.4	41.8	38.5
2	58	8.9	9.5	41.8	38.4
2	59	9.0	9.3	41.8	38.4
3	0	9.0	9.4	41.7	38.4
3	1	8.9	9.3	41.7	38.4
3	1	8.9	9.3	41.8	38.4
3	2	8.9	9.3	41.8	38.5
3	3	8.8	9.4	41.7	38.4
3	4	8.9	9.5	41.7	38.4
3	5	8.8	9.3	41.7	38.5
3	6	8.8	9.4	41.7	38.5
3	7	8.9	9.2	41.5	38.4
3	8	8.6	9.2	41.4	38.8
3	9	8.7	9.3	41.5	38.9
3	10	8.7	9.3	41.5	38.6
3	11	8.6	9.2	41.6	38.7
3	12	8.6	9.1	41.7	38.5
3	13	8.7	9.1	41.6	38.6
3	14	8.5	9.1	41.7	38.6
3	15	8.5	9.1	41.7	38.6
3	16	8.5	9.1	41.7	38.5
3	17	8.6	9.2	41.7	38.5
3	18	8.6	9.1	41.7	38.5
3	19	8.7	9.2	41.7	38.5
19	17	5.0	5.0	41.0	40.3
19	27	5.0	5.0	40.9	40.3
19	37	5.0	4.9	41.4	39.8
19	47	5.0	4.9	41.0	40.0
19	57	5.0	4.9	41.0	40.2
20	7	5.0	4.9	41.1	40.0
20	17	4.9	4.9	41.0	40.0
20	27	5.0	4.8	40.8	40.6
20	36	4.9	4.8	40.9	40.2
20	46	4.9	4.8	41.0	40.0
20	56	4.9	4.8	41.1	40.0
21	6	4.9	4.8	41.3	39.7
21	16	4.9	4.9	41.3	39.7
21	26	4.8	4.9	41.4	39.4
21	36	4.8	4.7	41.3	39.6

TIME FROM BEGINNING OF TEST		MOISTURE CONTENT			RELATIVE
		SAMPLE A	SAMPLE B	TEMPERATURE	HUMIDITY
HOURS	MINUTES	DRY BASIS	DRY BASIS	DEG. C	PERCENT
21	46	4.7	4.8	41.3	39.6
21	56	4.8	4.8	41.4	39.3
22	6	4.8	4.8	41.4	39.3
22	16	4.9	4.8	41.3	39.5
22	26	4.6	4.8	41.3	39.4
22	36	4.9	4.8	41.4	39.3
22	46	4.8	5.0	41.5	39.1
22	56	4.7	4.7	41.5	38.9
23	6	4.8	4.7	41.4	39.0

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