

## CHAPTER IV



### EXPERIMENTS

#### 4.1 Experimental Setup

The experimental setup is shown schematically in Figure 4.1. A triac for controlling the 3-phase electric current is connected to a 4.5 kW electric heater. C-C (copper-constantan) thermocouples are used to measure the temperatures of hot air at the inlet and outlet, and in bed of drying materials. The outputs (mv) from the thermocouples are recorded continuously with three channel recorder. Hot air at a constant flow rate is passed upward through a stainless steel screen on which a thin bed (3-8 cm) of drying materials is packed. The air flow rate is controlled by adjusting a main valve together with a by pass valve, and measured with an orifice meter. A inclined water manometer is connected to the orifice tapes.

#### 4.2 Experimental Procedure

##### 4.2.1 Preparation of Drying Materials

1. The materials, usually fruit, are washed to remove superficial impurities.
2. Next they are dipped in a 0.2 wt % sodium hydroxide solution at a temperature  $50^{\circ}\text{C}$  for about 20 seconds (The exceptions are star-goose berry and sapota).
3. Then they are rinsed with cold water and drained as completely as possible.

##### 4.2.2 Drying

1. Air is supplied to the dryer by a blower
2. The air velocity is controlled by the main valve

together with the bypass valve, the velocity being measured by the orifice meter. Difference in the water levels in the manometer is recorded and kept constant.

3. The electric heater is switched on to heat the air, the air temperature being controlled with a triac, measured with a thermocouples and recorded continuously on the recorder.

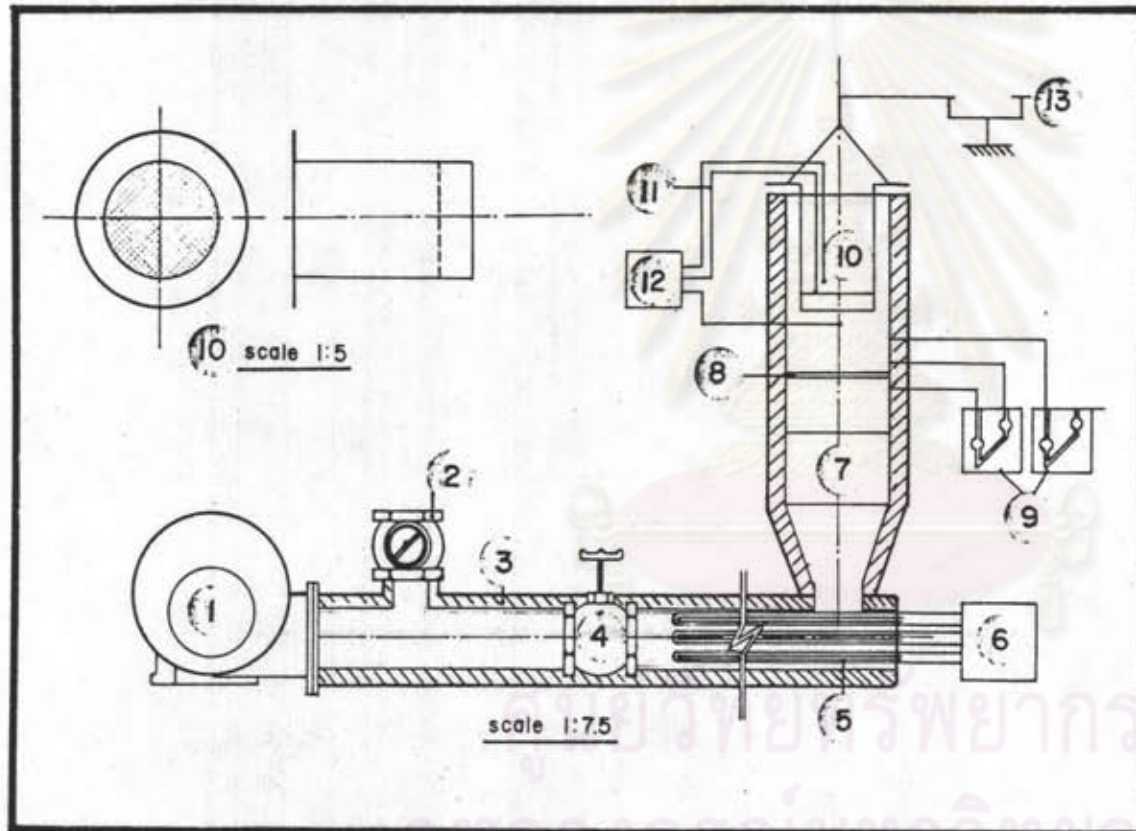
4. The hot air is then passed through a bed of 1.5 cm glassbeads to ensure uniform flow. A sufficient length of time is allowed for the empty dryer to reach a steady state.

5. The stainless steel container (a basket with a screen bottom) is weighed on a balance before the desired amount of drying materials is placed in it to a height of 3-8 cm. The drying time is counted from the moment the container is inserted back into the dryer

6. To determine of the drying rate, the container is removed from the dryer at appropriate intervals for weighing. The time, container weight, wet bulb and dry bulb temperatures of ambient air and pressure drop through the packed bed are recorded.

7. Step 6 is repeated every 15-60 minutes until the equilibrium moisture content is reached, that is, no further decrease in weight is detected after a couple of hours.

8. A portion of the dried material is placed in a vacuum dryer and kept at  $85^{\circ}\text{C}$  for 2-3 days to determine the weight of the solid materials.



1. BLOWER
2. BY PASS VALVE
3. INSULATOR
4. MAIN VALVE
5. HEATER
6. WATT CONTROLLER
7. GLASS BEADS
8. ORIFIC PLATE
9. INCLINED MANOMETER
10. STAINLESS STEEL CONTAINER
11. THERMOCOUPLES
12. MILLIVOLTS RECORDER
13. BALANCE

FIGURE 4.1 SCHEMATIC DIAGRAM OF EXPERIMENTAL APPARATUS

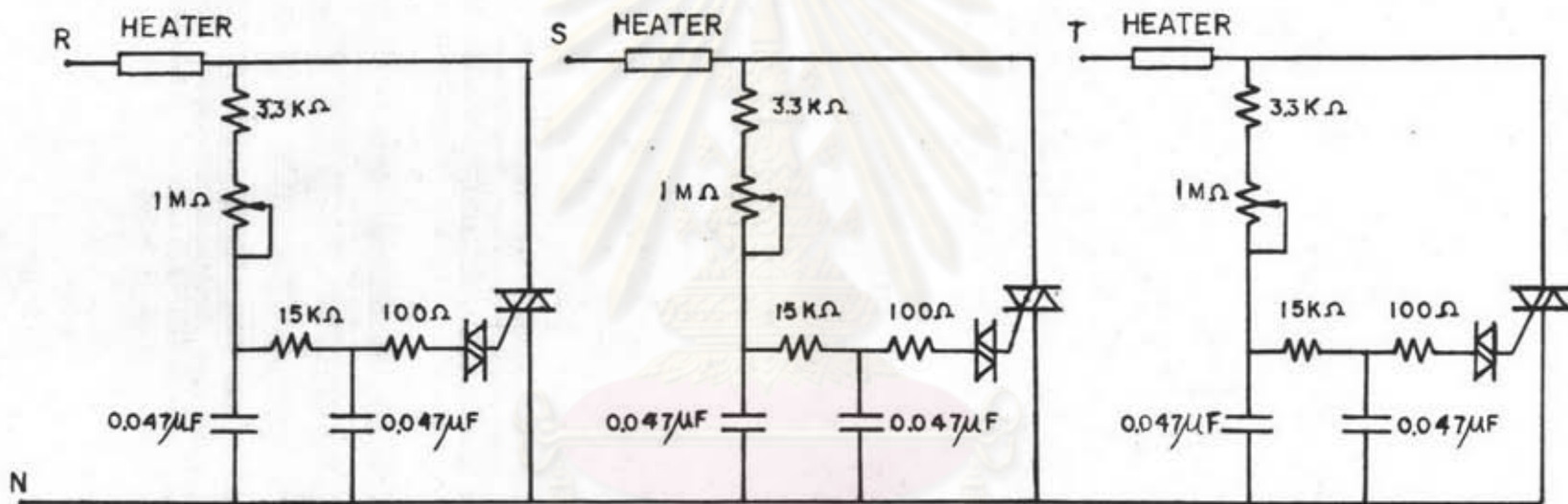


FIGURE 4.2 CIRCUIT DIAGRAM OF TRIAC

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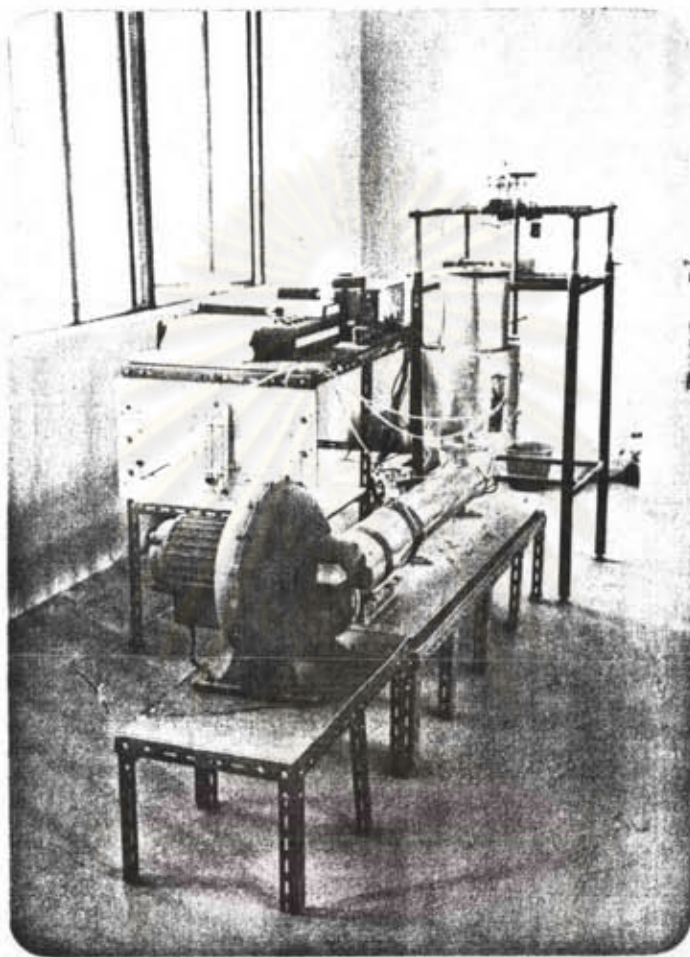


FIGURE 4.3 PHOTO OF EXPERIMENTAL APPARATUS

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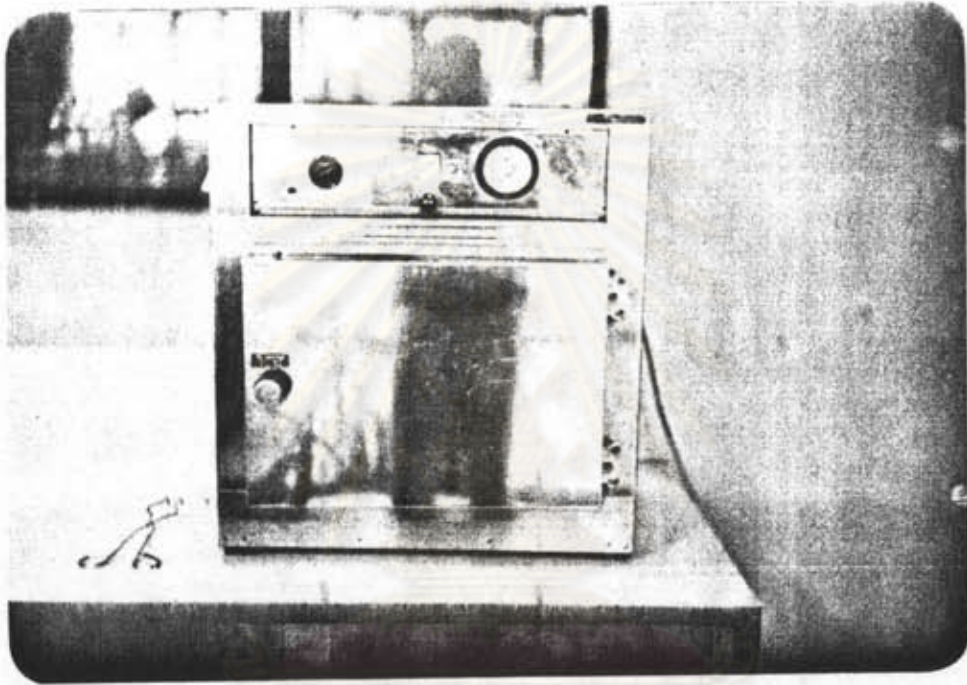


FIGURE 4.4 PHOTO OF A VACUUM DRYER

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### 4.3 Experimental Conditions

Experiments were carried out under the conditions summarized in Table 4.1, 4.2 and 4.3

TABLE 4.1 DRYING CONDITIONS FOR JUJUBE (A)

Run No.	Sample Wt. (g)	Drying Temp. (°c)	Air Velocity (m/s)	Rel. Humidity (%)	Pre-Treatment
A.1	336.1	55	0.6	20	yes
A.2	331.1	72	0.6	8	yes
A.3	384.1	55	1.2	22	yes
A.4	345.1	72	1.2	10	yes
A.5	601.1	72	1.2	9	yes

TABLE 4.2 DRYING CONDITIONS FOR SAPOTA (B)

Run No.	Sample Wt. (g)	Drying Temp. (°c)	Air Velocity (m/s)	Rel. Humidity (%)	Pre-Treatment
B-1	424.6	55	1.2	10	No
B-2	447.4	72	1.2	9	No
B-3	386.5	72	0.6	7	No
B-4	449.3	55	0.6	20	No

TABLE 4.3 DRYING CONDITIONS FOR GRAPE (C) AND STAR-GOOSE BERRY(D)

Run No	Sample Wt. (g)	Drying Temp. (°c)	Air Velocity (m/s)	Rel Humidity (%)	Pre-Treatment
C-1	300.0	65	0.6	12	Yes
C-2	304.6	72	1.2	9	Yes
C-3	341.9	55	1.2	22	Yes
C-4	274.2	55	0.6	8	Yes
D-1	275.2	55	0.6	16	No

#### 4.4 Experimental Results

The material was weighed at an appropriate time interval  $\Delta t$  and the moisture content  $W_d$  was computed from

$$W_d = \frac{m - m_d}{m_d}$$

where  $m$  = weight of material at time  $t$  (kg)

$m_d$  = weight of bone dry solid (kg)

$$\text{Drying Rate}(R_w) = \frac{\text{weight of evaporated water}}{\text{weight of dry solid} \cdot \text{time}} \quad (\text{kg water/kg dry solid} \cdot \text{hr})$$

##### 4.4.1 Drying Rate at Various Air Temperature

In this case, the air velocity was kept constant at 0.6 m/s and 1.2 m/s, respectively, while the temperature was varied from 55°C to 72°C. The results are shown in Figures 4.5, 4.8, 4.9,



4.13, 4.14, 4.17, 4.18, 4.21, 4.22, 4.24 and 4.25.

#### 4.4.2 Drying Rate at Various Air Velocity

In this case, air temperature in the dryer was kept approximately at either 55<sup>o</sup>c or 72<sup>o</sup>c, while the air velocity was varied at 0.6 m/s and 1.2 m/s, respectively. Figures 4.6, 4.15, 4.16 and 4.23 show the plots of moisture content versus time. Figures 4.10, 4.11 4.19 and 4.26 show the plots of drying rate versus moisture content.

#### 4.4.3 Drying Rate for Various Bed Heights

In this case, the air was kept at 1.2 m/s while the sample weight was either 345.1 g or 601.0 g. in Table 4.1. The results are shown in Figures 4.7 and 4.12.

#### 4.4.4 Equilibrium Moisture Content

Equilibrium moisture content for various agricultural products was determined and is shown in Table 4.4.



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TABLE 4.4 EQUILIBRIUM MOISTURE CONTENT FOR VARIOUS PRODUCTS

Run No	Rel.Humidity %	Drying Temp. °c	Equilibrium moisture content
A-3	22	55	0.5197
A-4	10	72	0.3214
B-1	11	55	0.2939
B-2	9	72	0.0915
B-3	7	72	0.0892
B-4	20	55	0.4396
C-2	9	72	0.3383
C-3	22	55	0.4744
C-4	8	55	0.1779
D-1	16	55	0.1679

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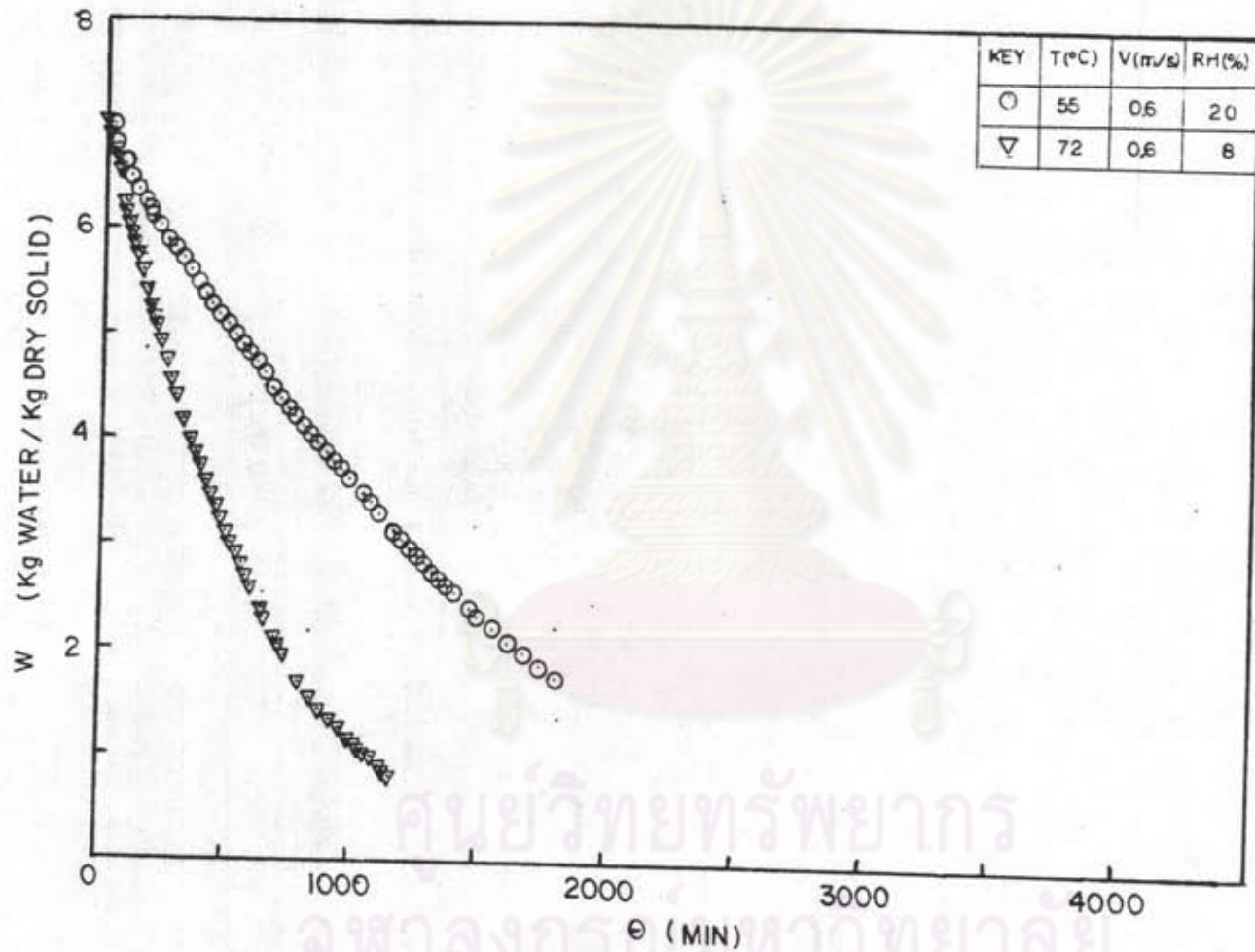


FIG.4.5 MOISTURE CONTENT VS. TIME FOR JUJUBE AT VARIOUS AIR TEMPERATURES

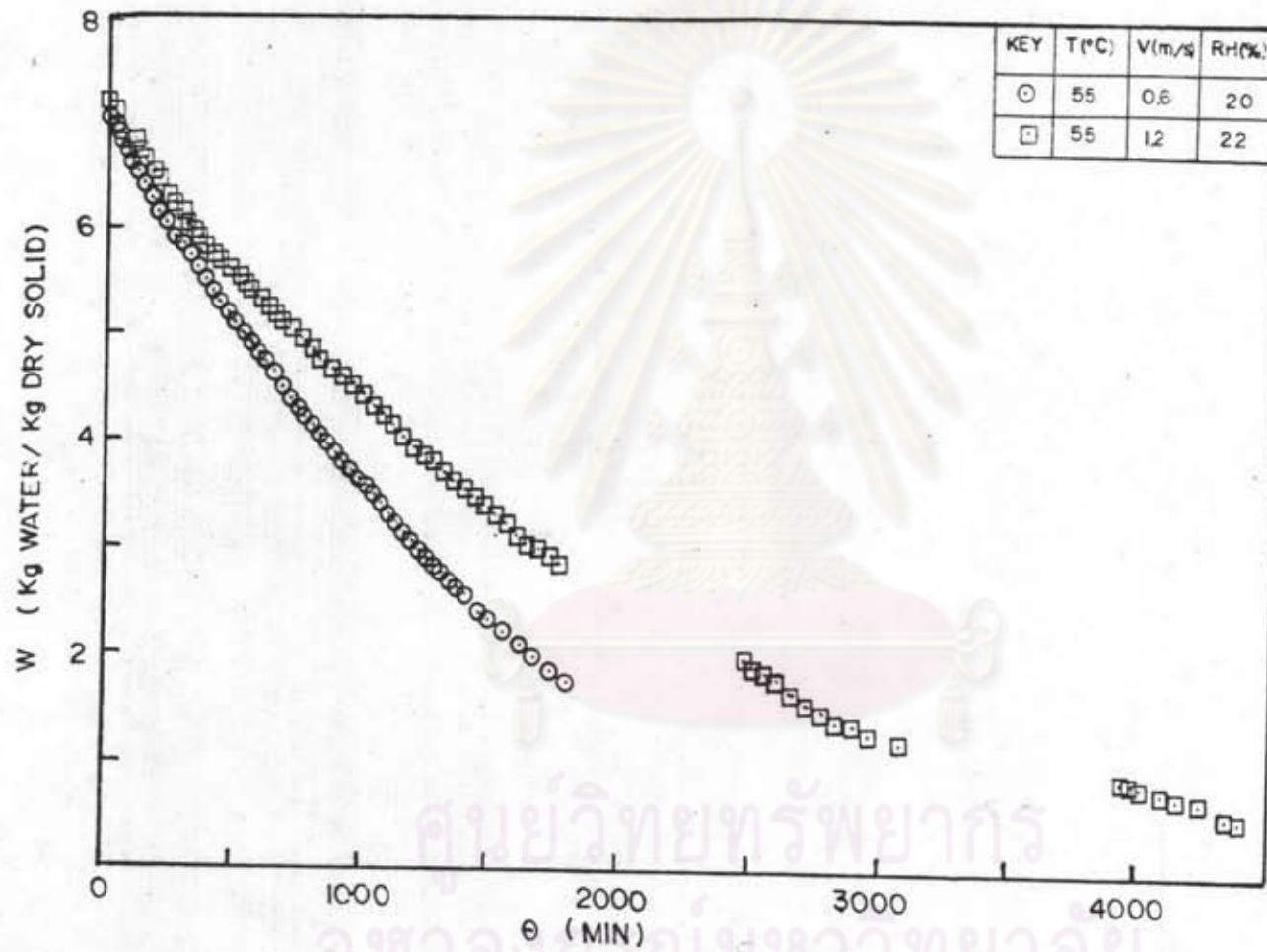


FIG4.6 MOISTURE CONTENT VS. TIME FOR JUJUBE AT VARIOUS AIR VELOCITIES

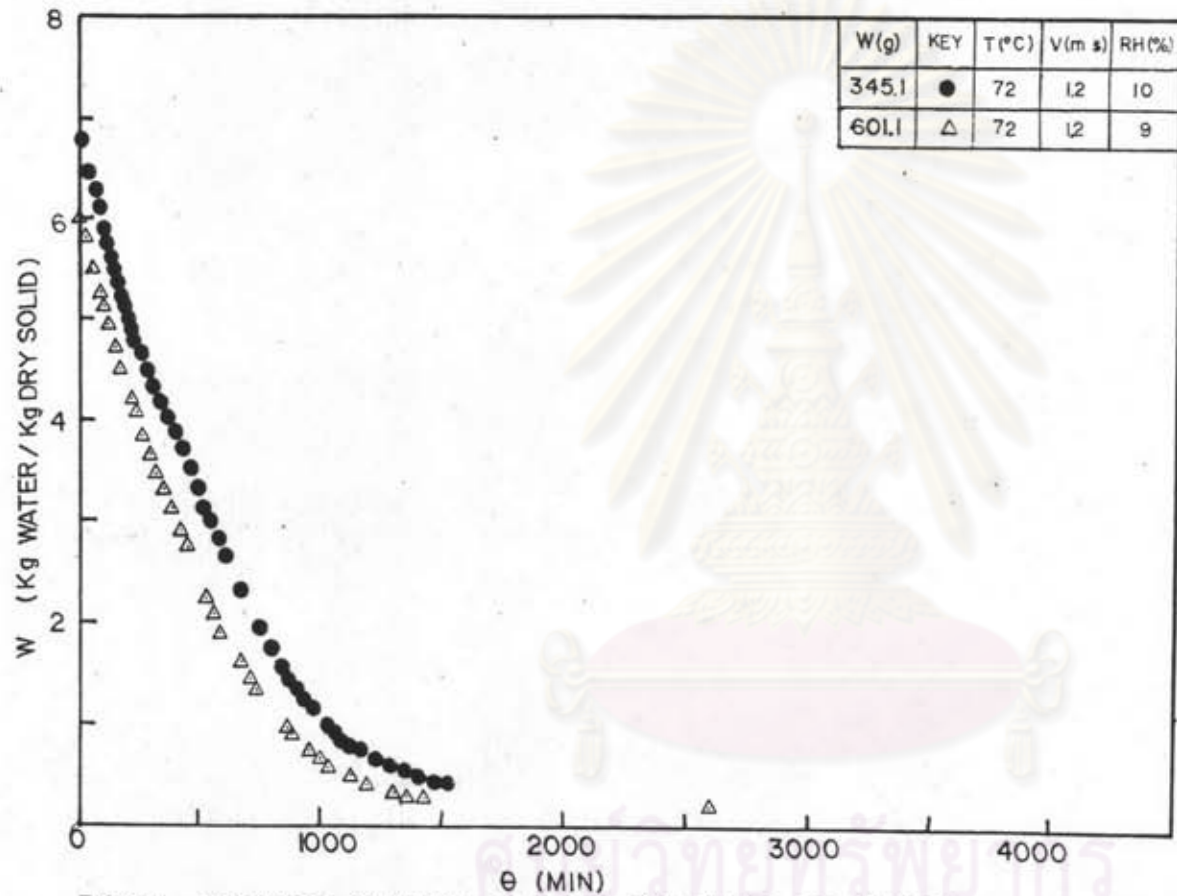


FIG.4.7 MOISTURE CONTENT VS. TIME FOR JUJUBE OF VARIOUS BED HEIGHTS

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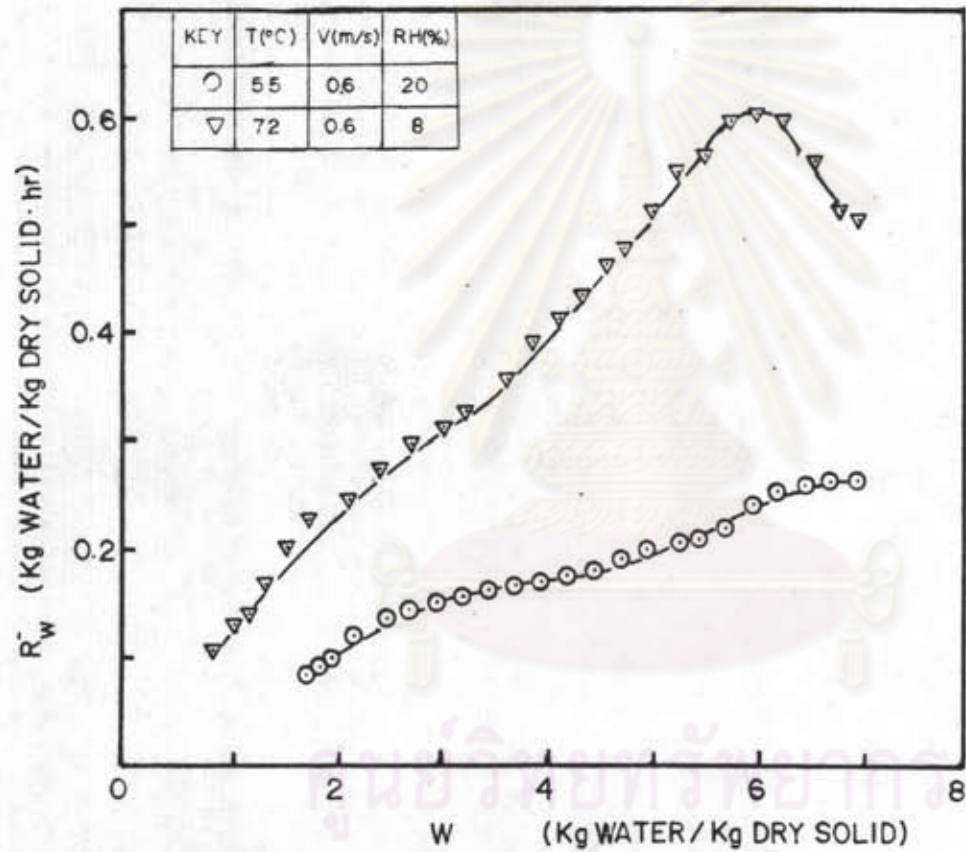


FIG.4.8 DRYING CHARACTERISTIC CURVE OF JUJUBE AT VARIOUS AIR TEMPERATURES

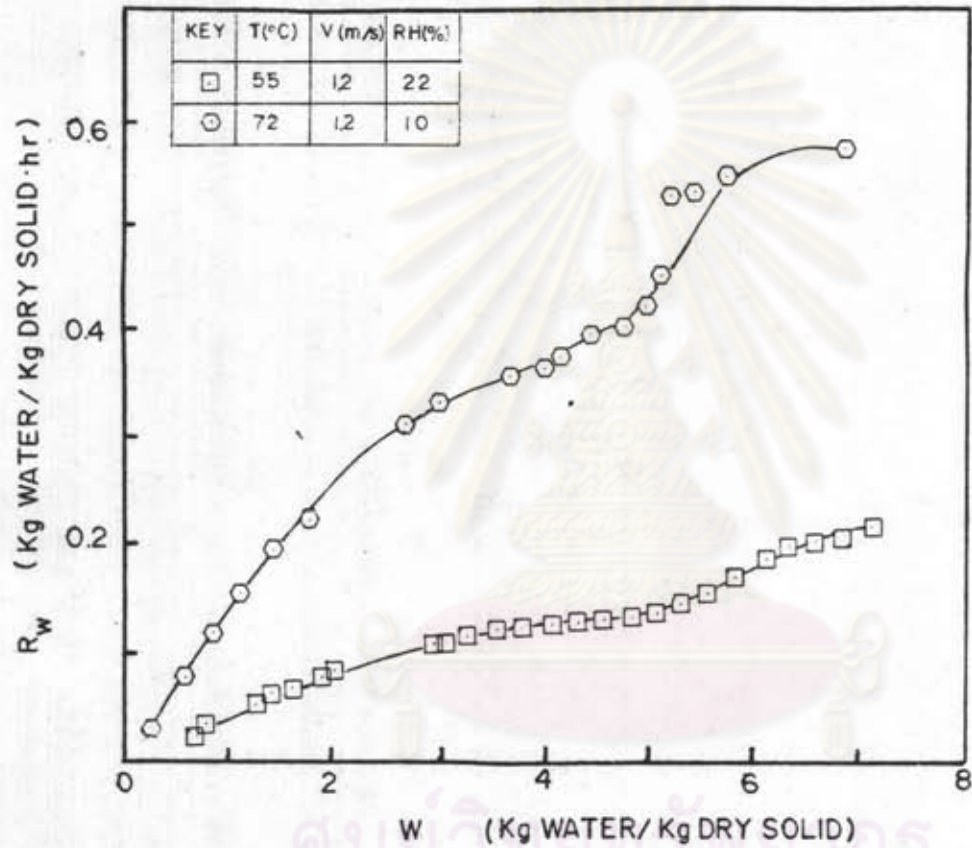


FIG.4.9 DRYING CHARACTERISTIC CURVE OF JUJUBE AT VARIOUS AIR TEMPERATURES



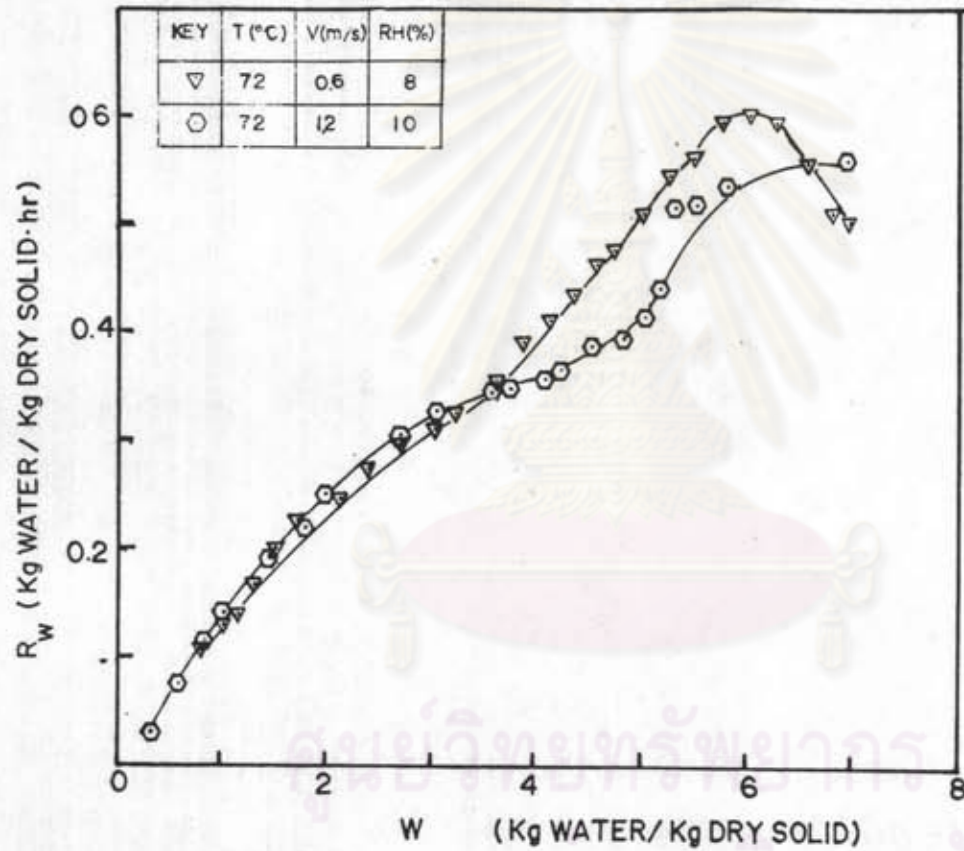


FIG. 4.10 DRYING CHARACTERISTIC CURVE OF JUJUBE  
AT VARIOUS AIR VELOCITIES



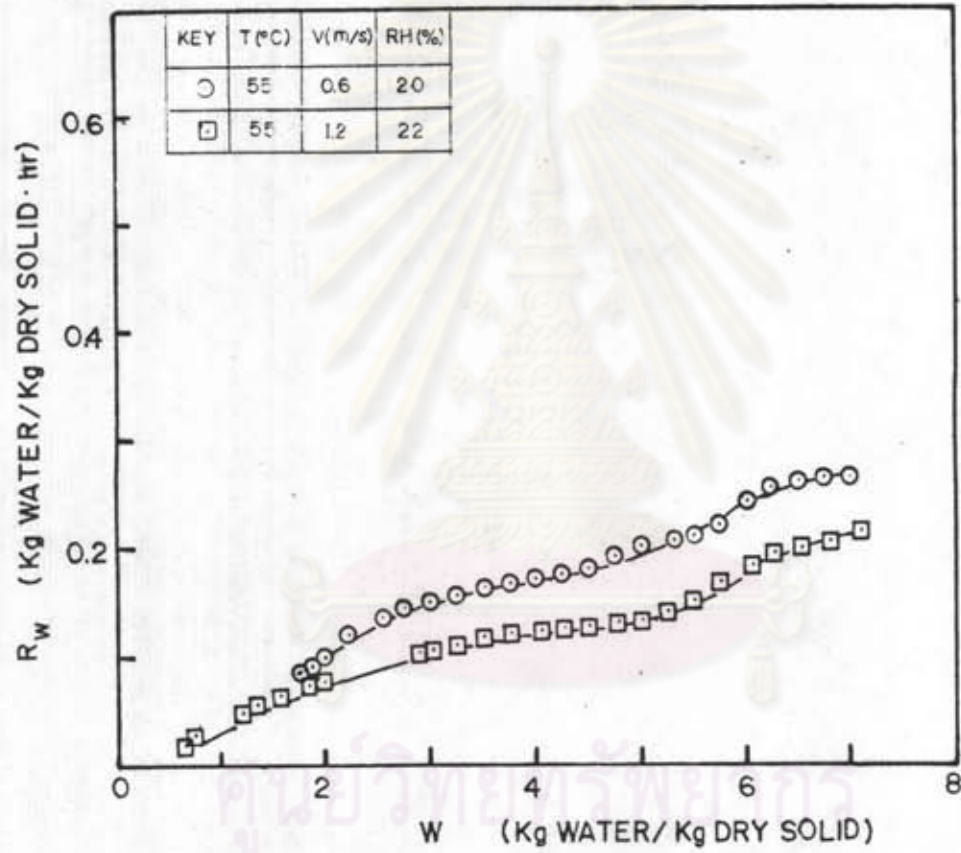


FIG. 4.11 DRYING CHARACTERISTIC CURVE OF JWUBE AT VARIOUS AIR VELOCITIES

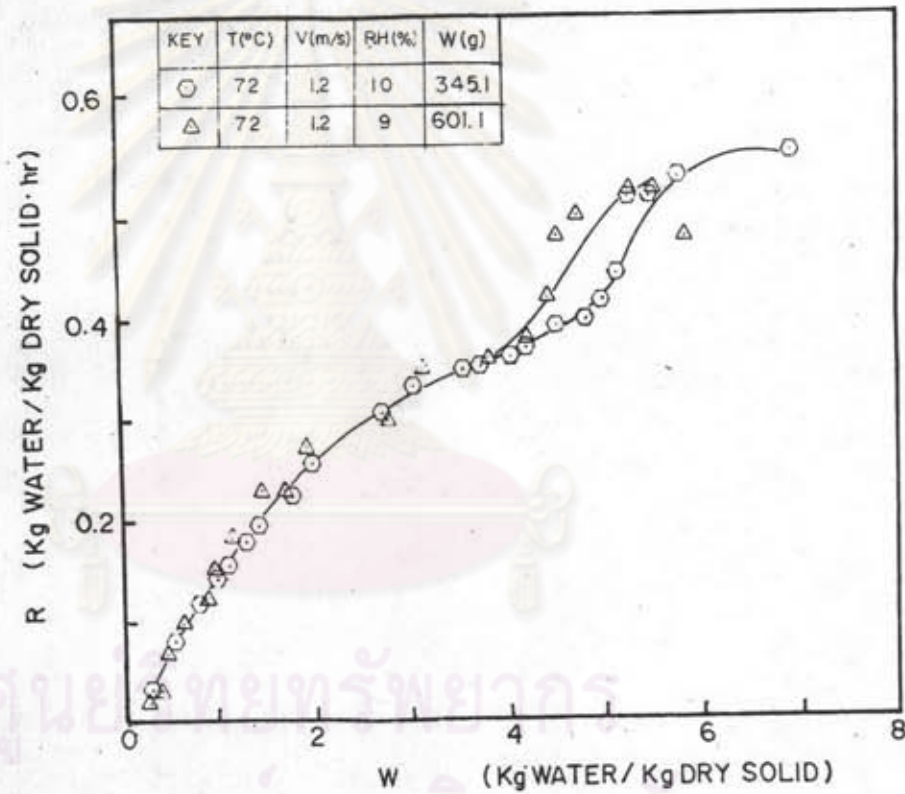


FIG. 4.12 DRYING CHARACTERISTIC CURVE OF JUJUBE OF VARIOUS BED HEIGHTS

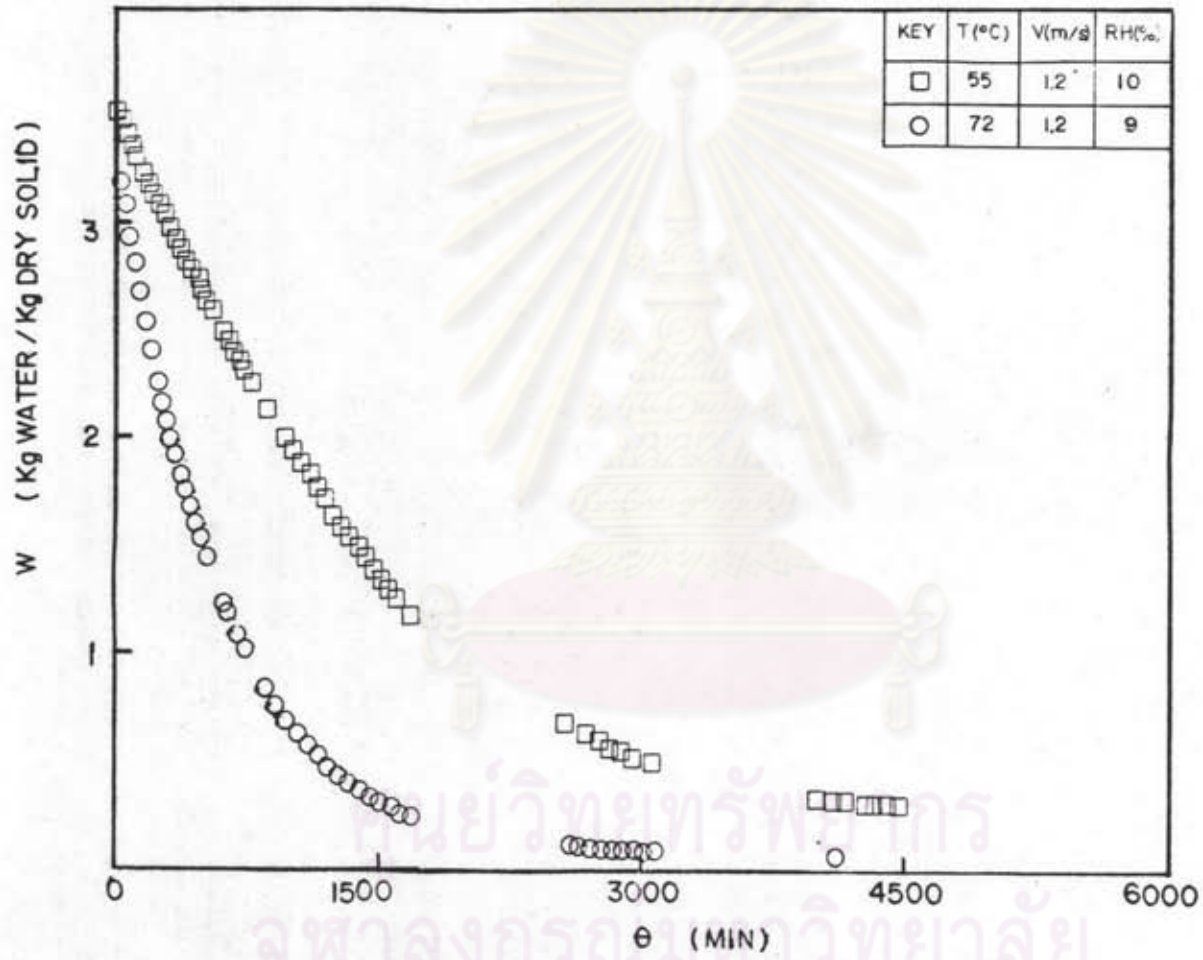


FIG.4.13 MOISTURE CONTENT VS. TIME FOR SAPOTA AT VARIOUS AIR TEMPERATURES

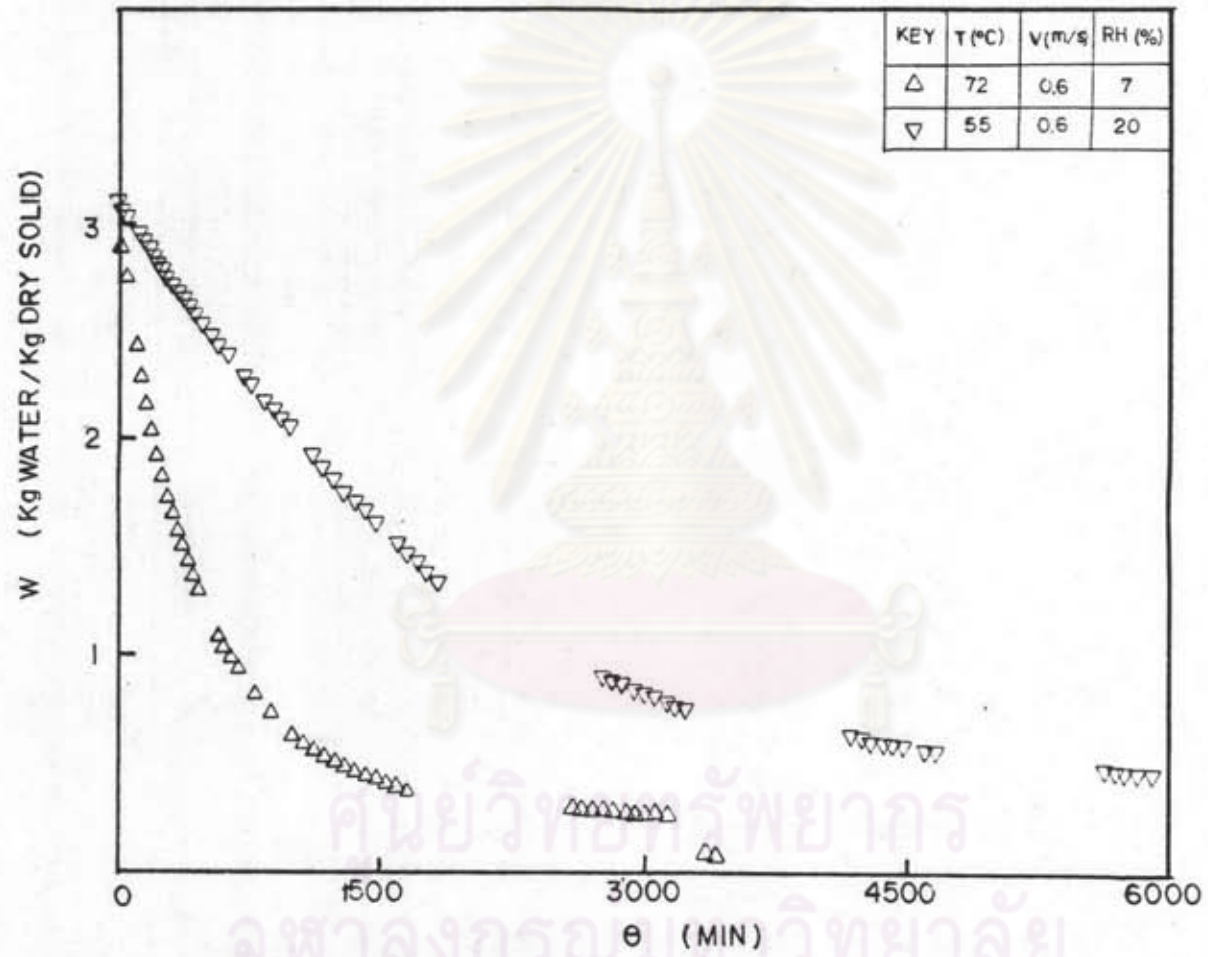


FIG. 4.14 MOISTURE CONTENT VS. TIME FOR SAPOTA AT VARIOUS AIR TEMPERATURES

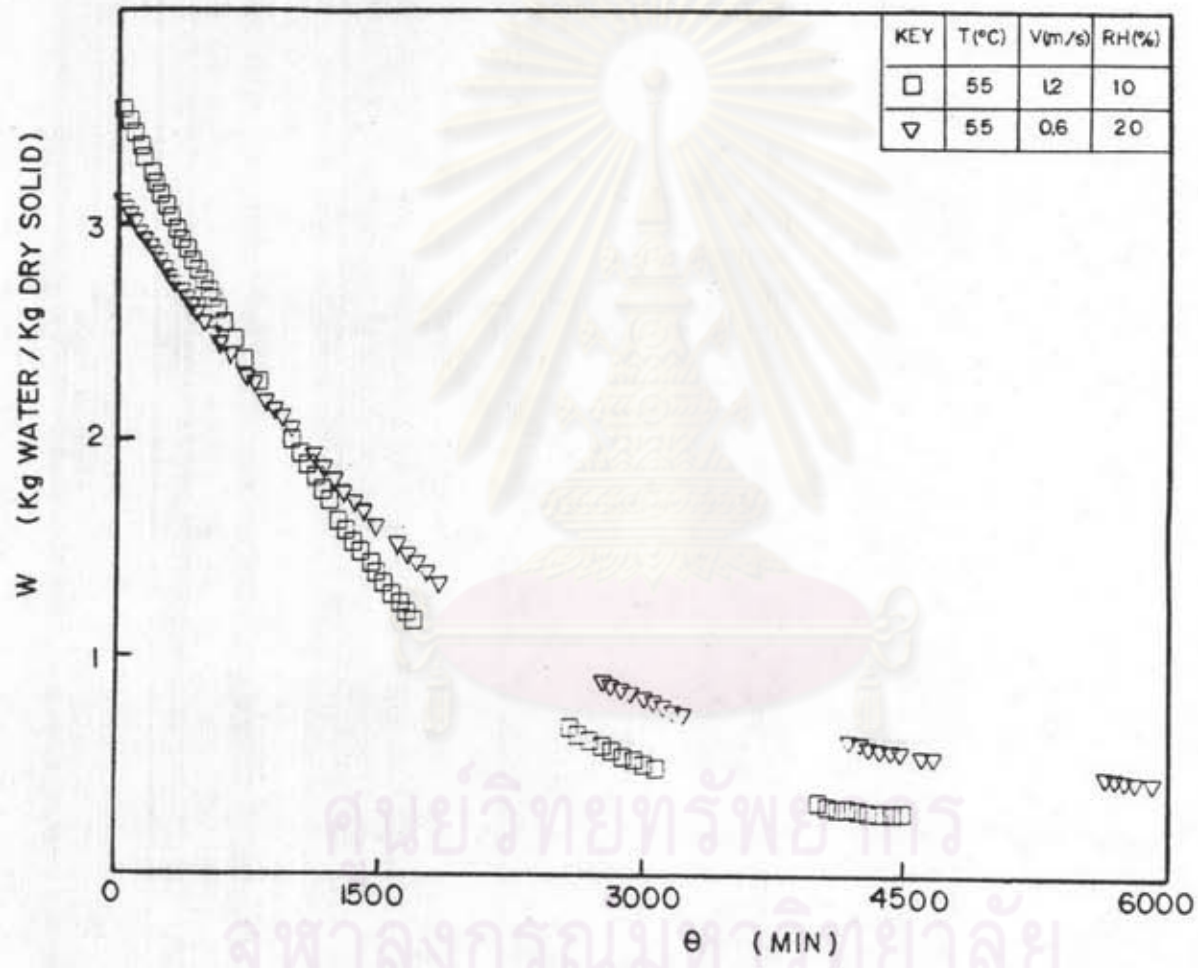


FIG.4.15 MOISTURE CONTENT VS. TIME FOR SAPOTA AT VARIOUS AIR VELOCITIES



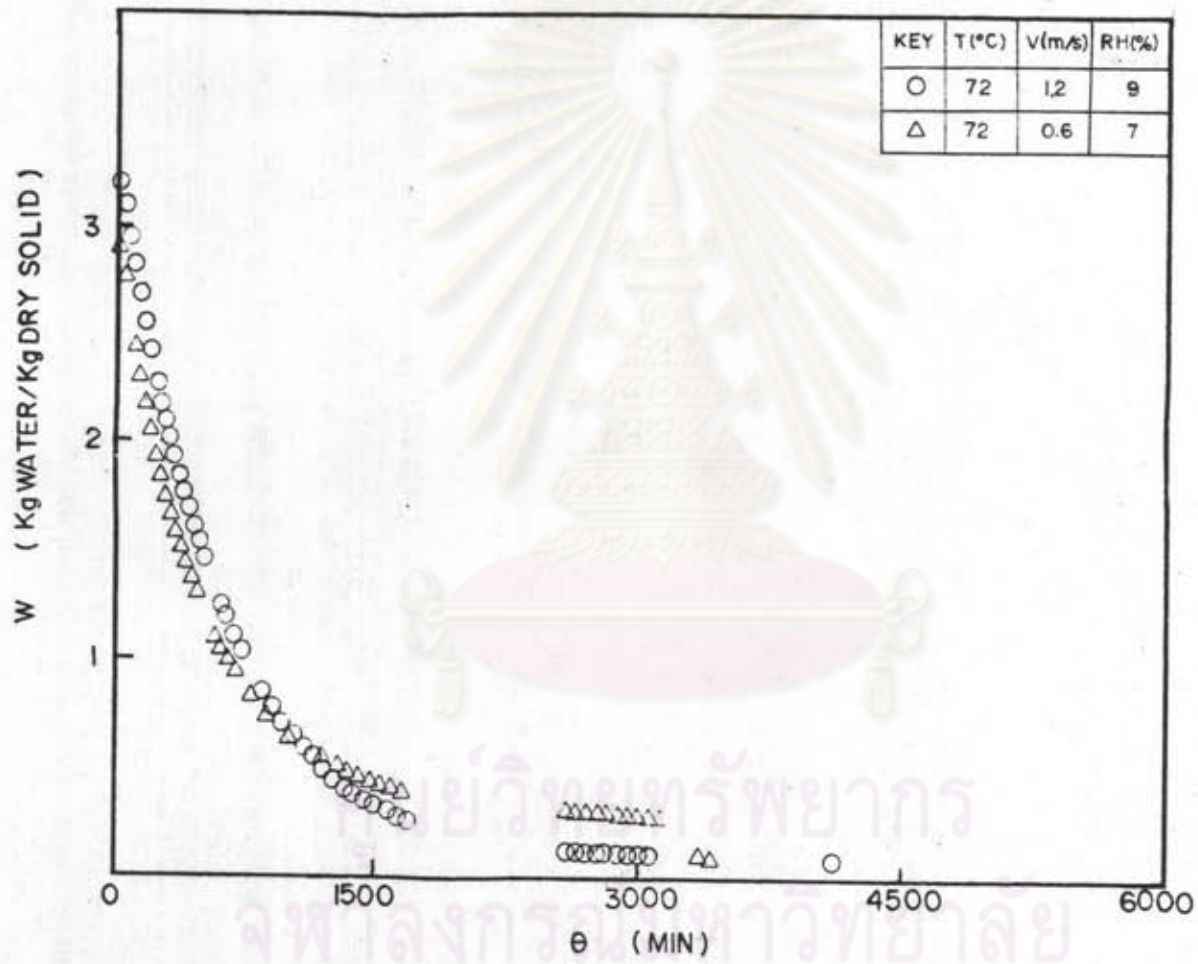


FIG. 4.16 MOISTURE CONTENT VS. TIME FOR SAPOTA AT VARIOUS AIR VELOCITIES

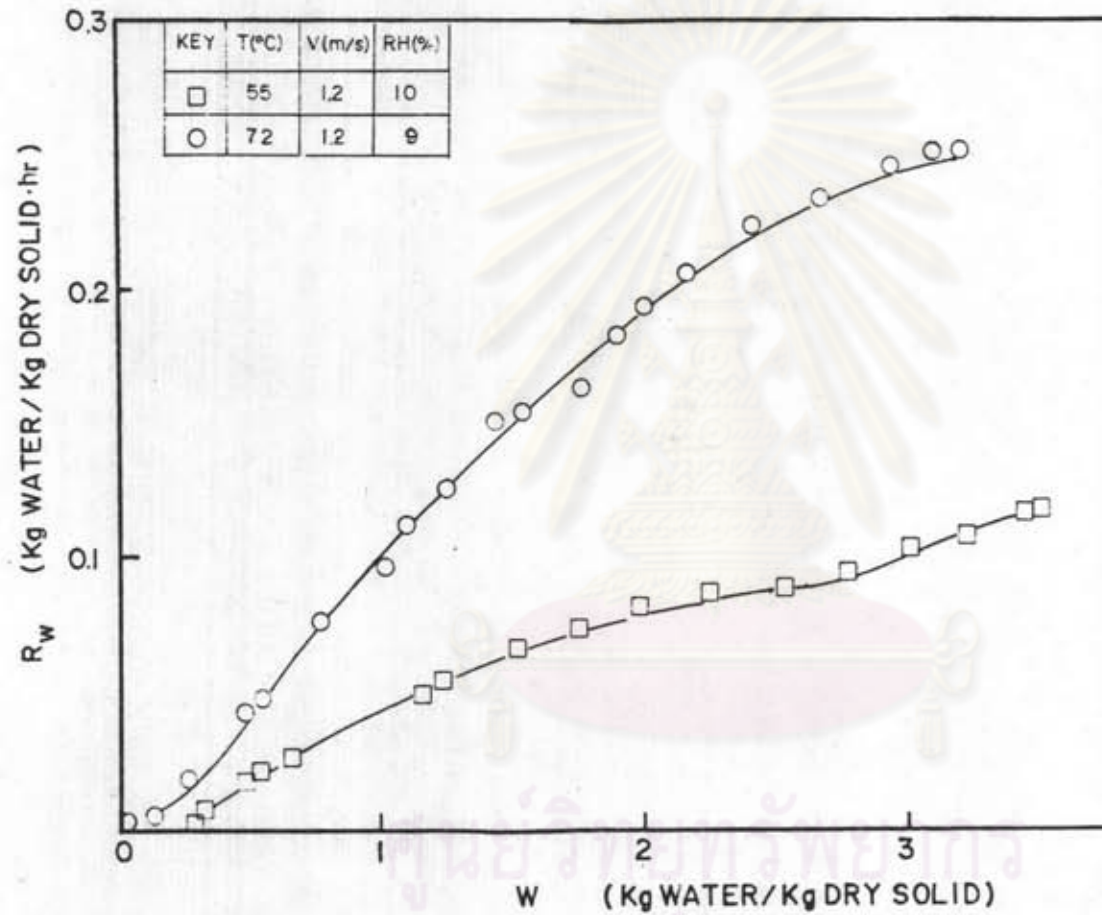


FIG. 4.17 DRYING CHARACTERISTIC CURVE OF SAPOTA AT VARIOUS AIR TEMPERATURES

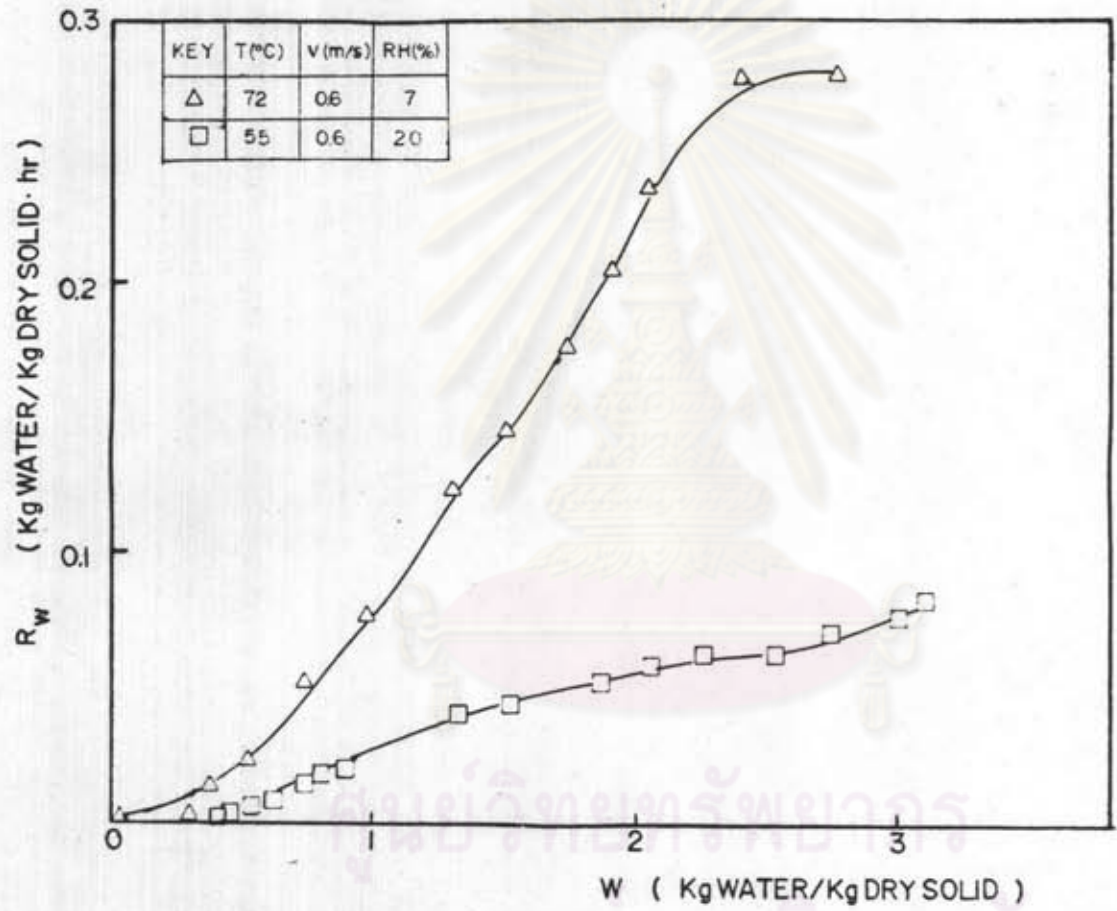


FIG. 4.18 DRYING CHARACTERISTIC CURVE OF SAPOTA AT VARIOUS AIR TEMPERATURES



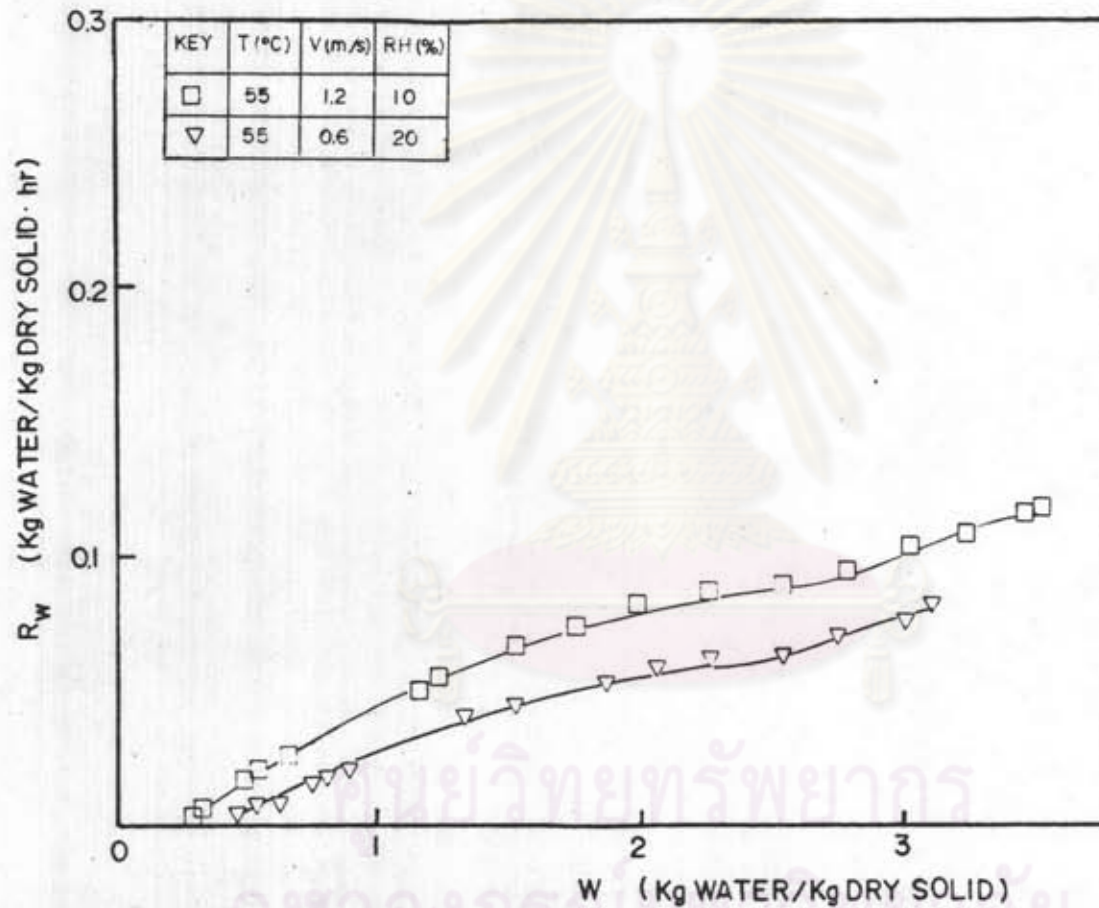


FIG.4.19 DRYING CHARACTERISTIC CURVE OF SAPOTA AT VARIOUS VELOCITIES

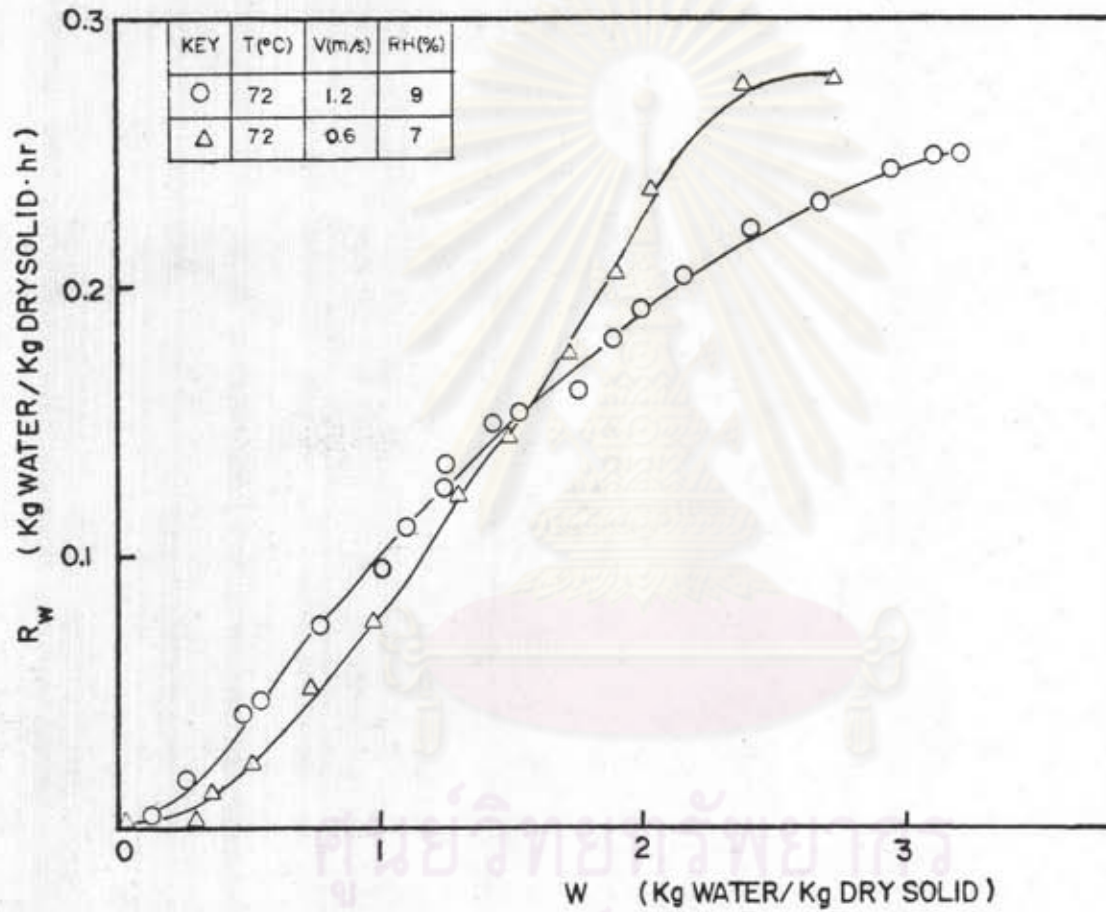


FIG. 4.20 DRYING CHARACTERISTIC CURVE OF SAPOTA AT VARIOUS AIR VELOCITIES

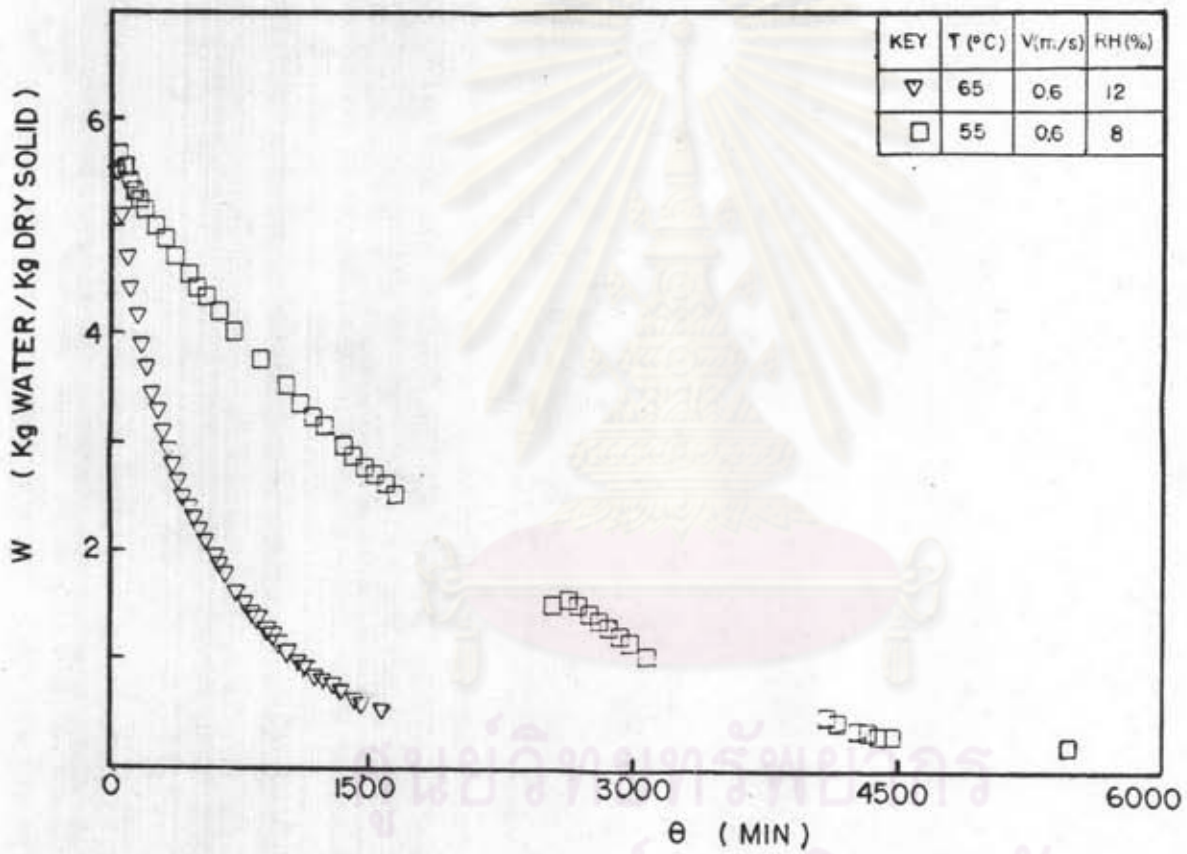


FIG.4.21 MOISTURE CONTENT VS. TIME FOR GRAPE AT VARIOUS AIR TEMPERATURES

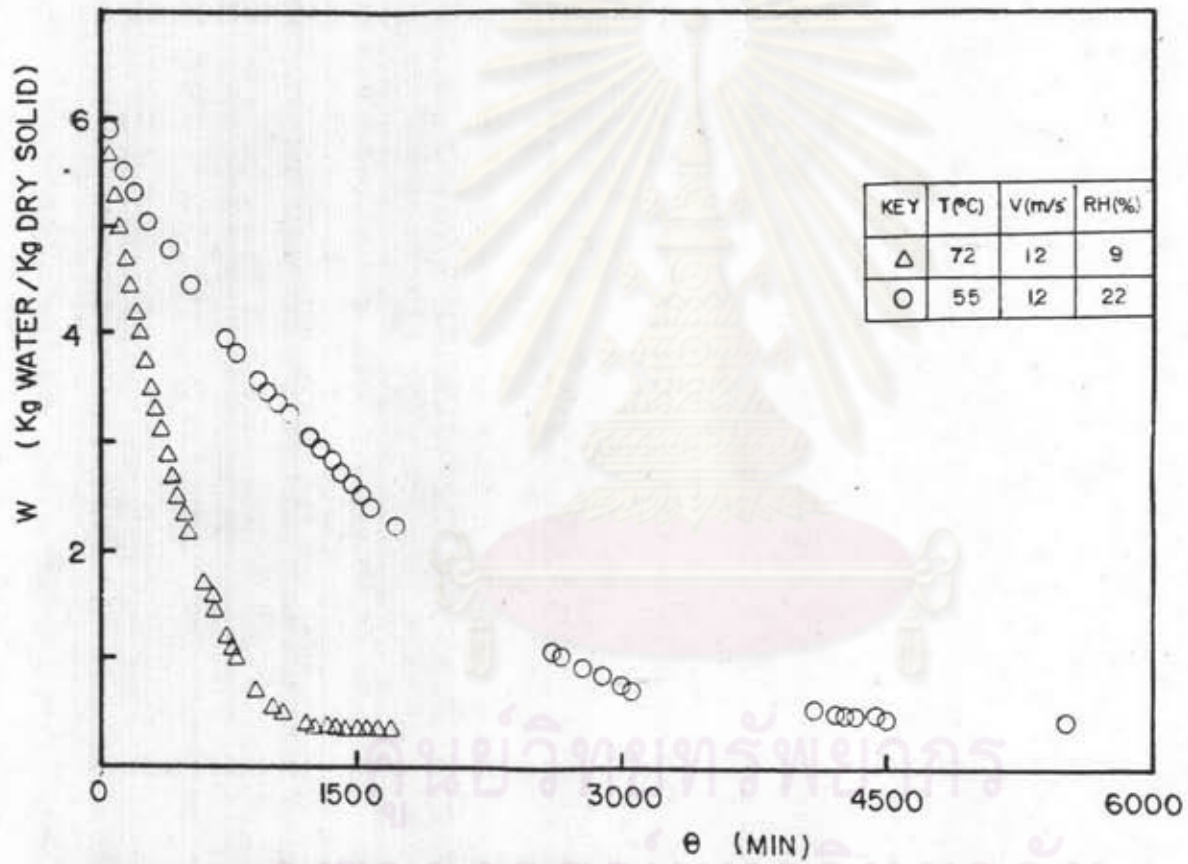


FIG.4.22 MOISTURE CONTENT VS. TIME FOR GRAPE AT VARIOUS TEMPERATURES

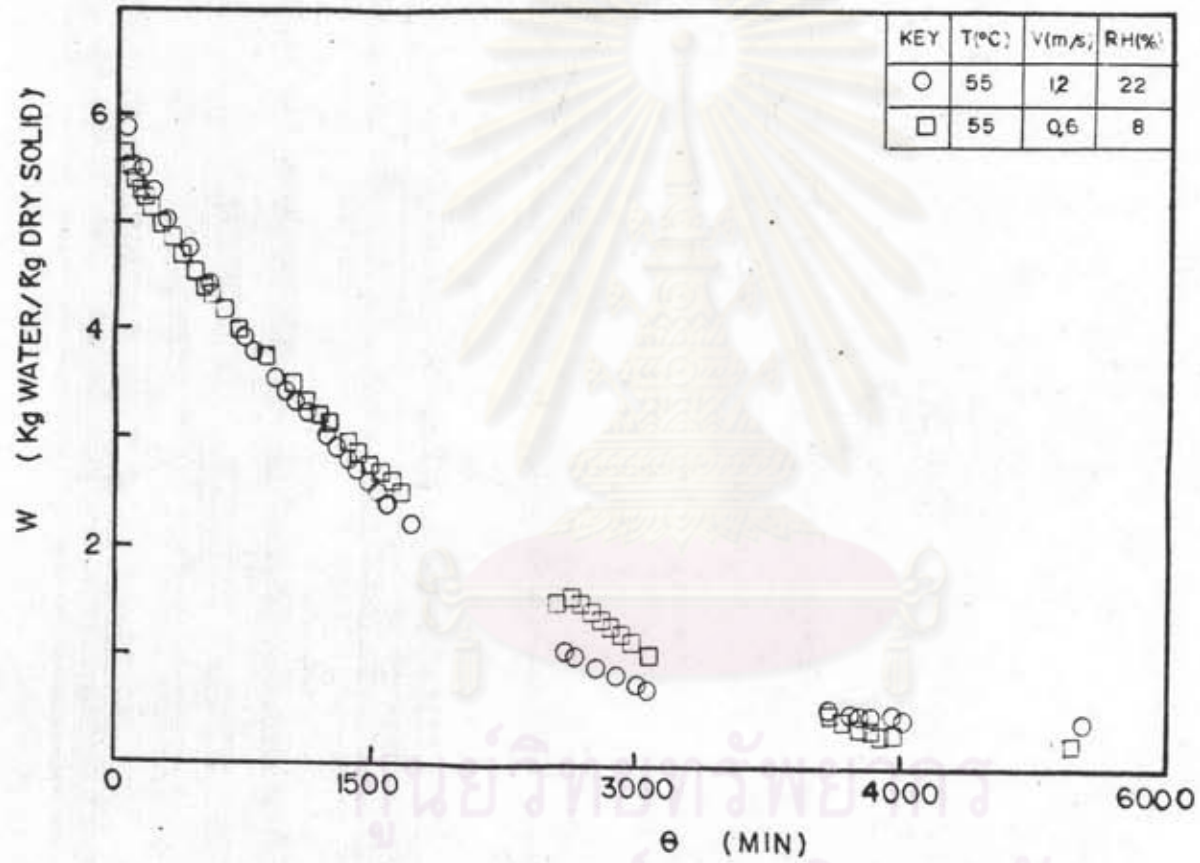


FIG.4.23 MOISTURE CONTENT VS. TIME FOR GRAPE AT VARIOUS AIR VELOCITIES

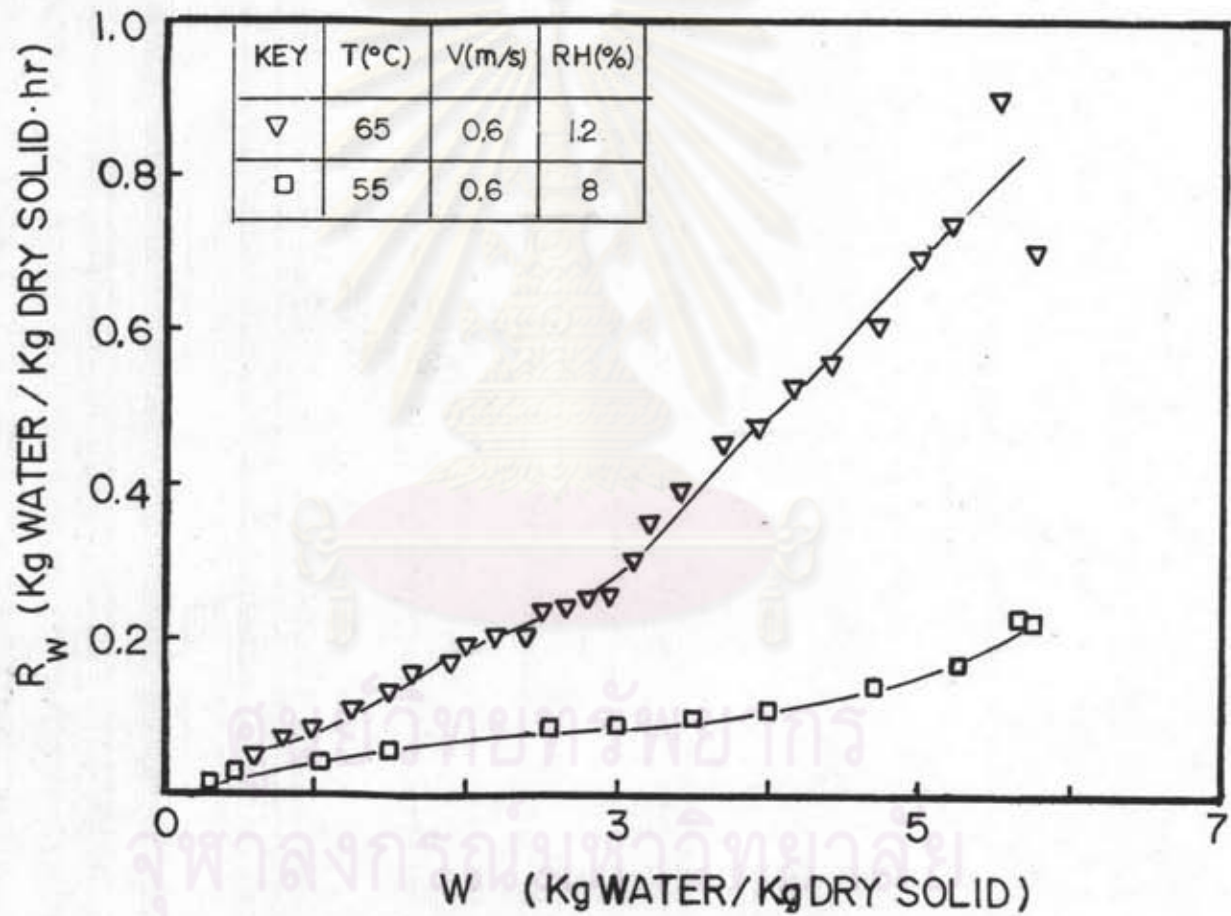


FIG.4.24 DRYING CHARACTERISTIC CURVE OF GRAPE AT VARIOUS AIR TEMPERATURES

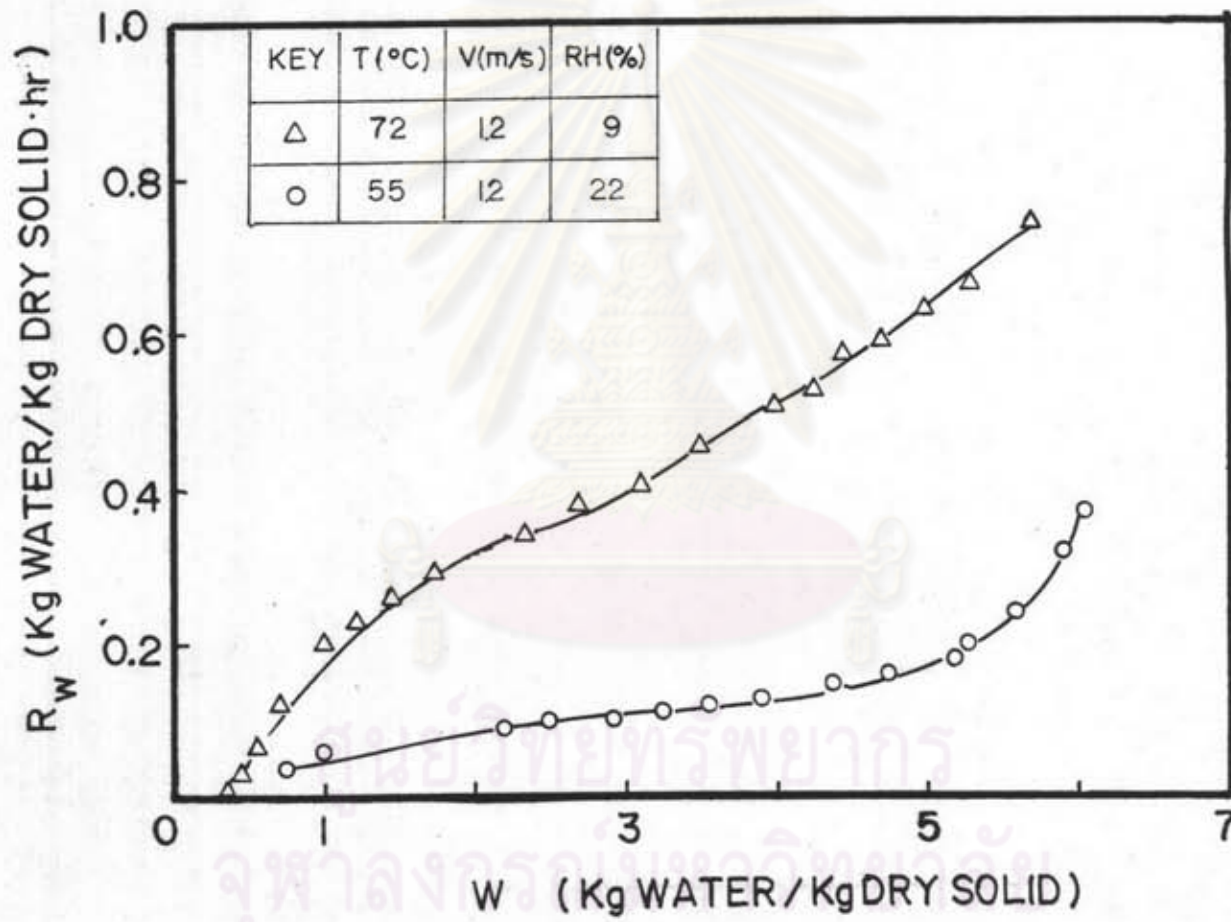


FIG.4.25 DRYING CHARACTERISTIC CURVE OF GRAPE AT VARIOUS AIR TEMPERATURES

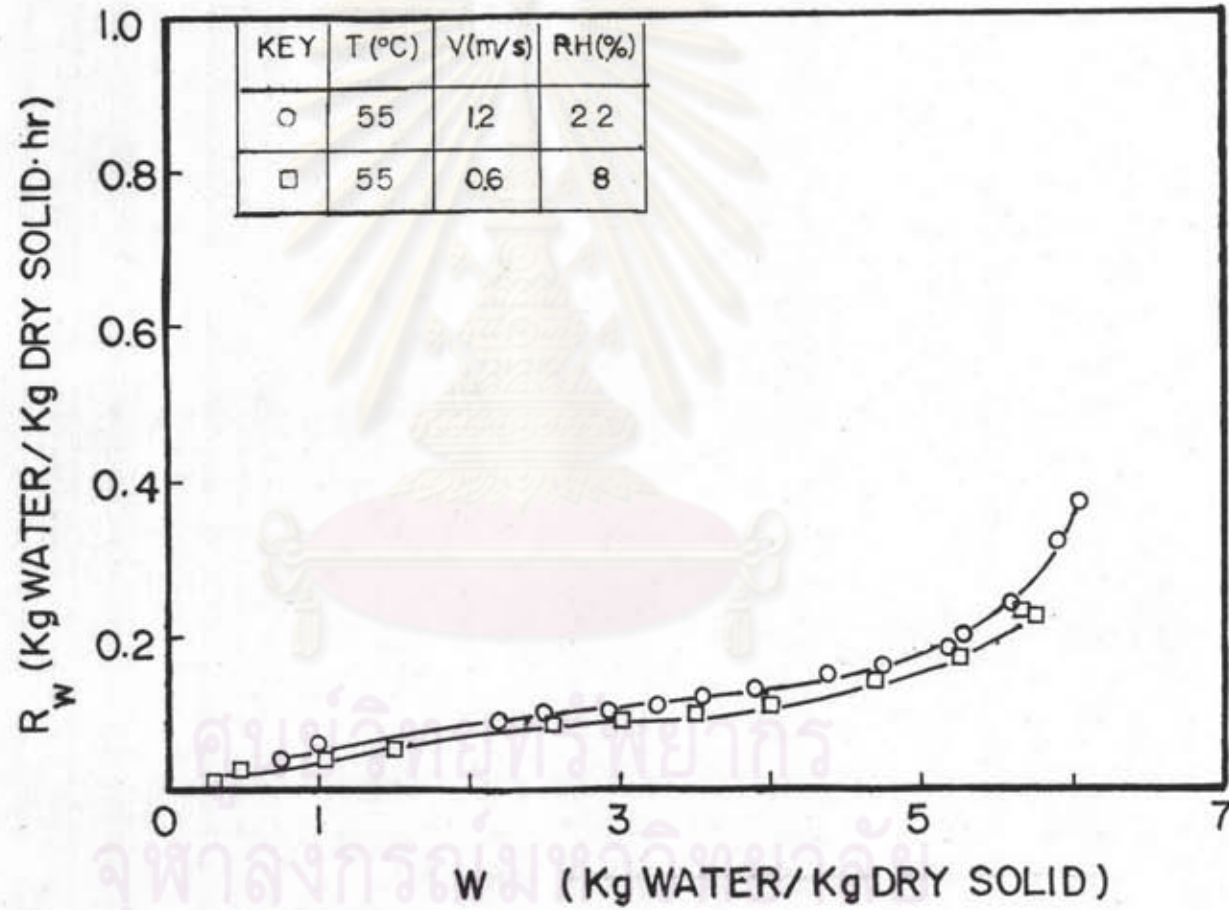


FIG.4.26 DRYING CHARACTERISTIC CURVE OF GRAPE AT VARIOUS AIR VELOCITIES



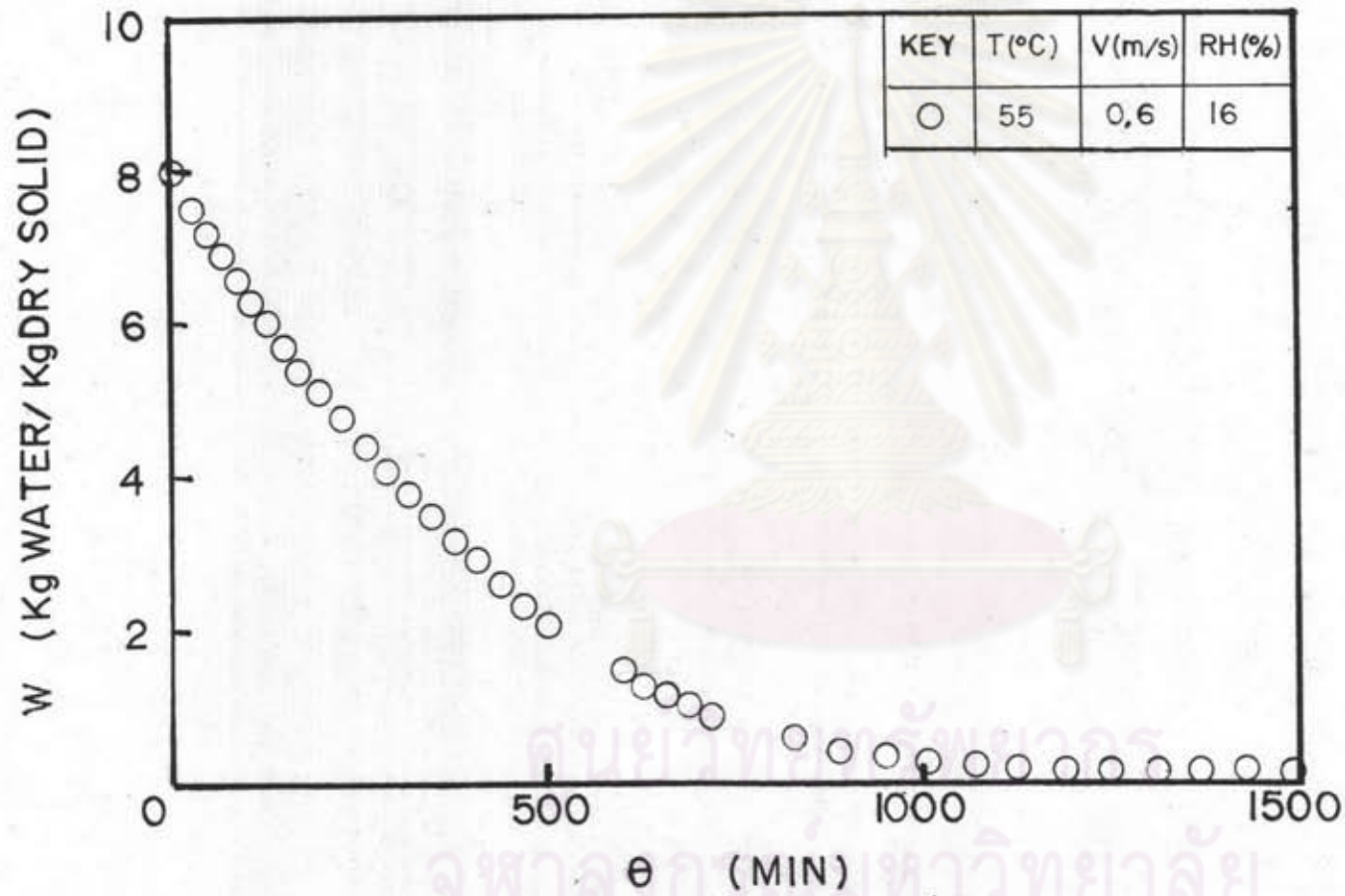


FIG.4.27 MOISTURE CONTENT VS. TIME FOR STAR-GOOSEBERRY

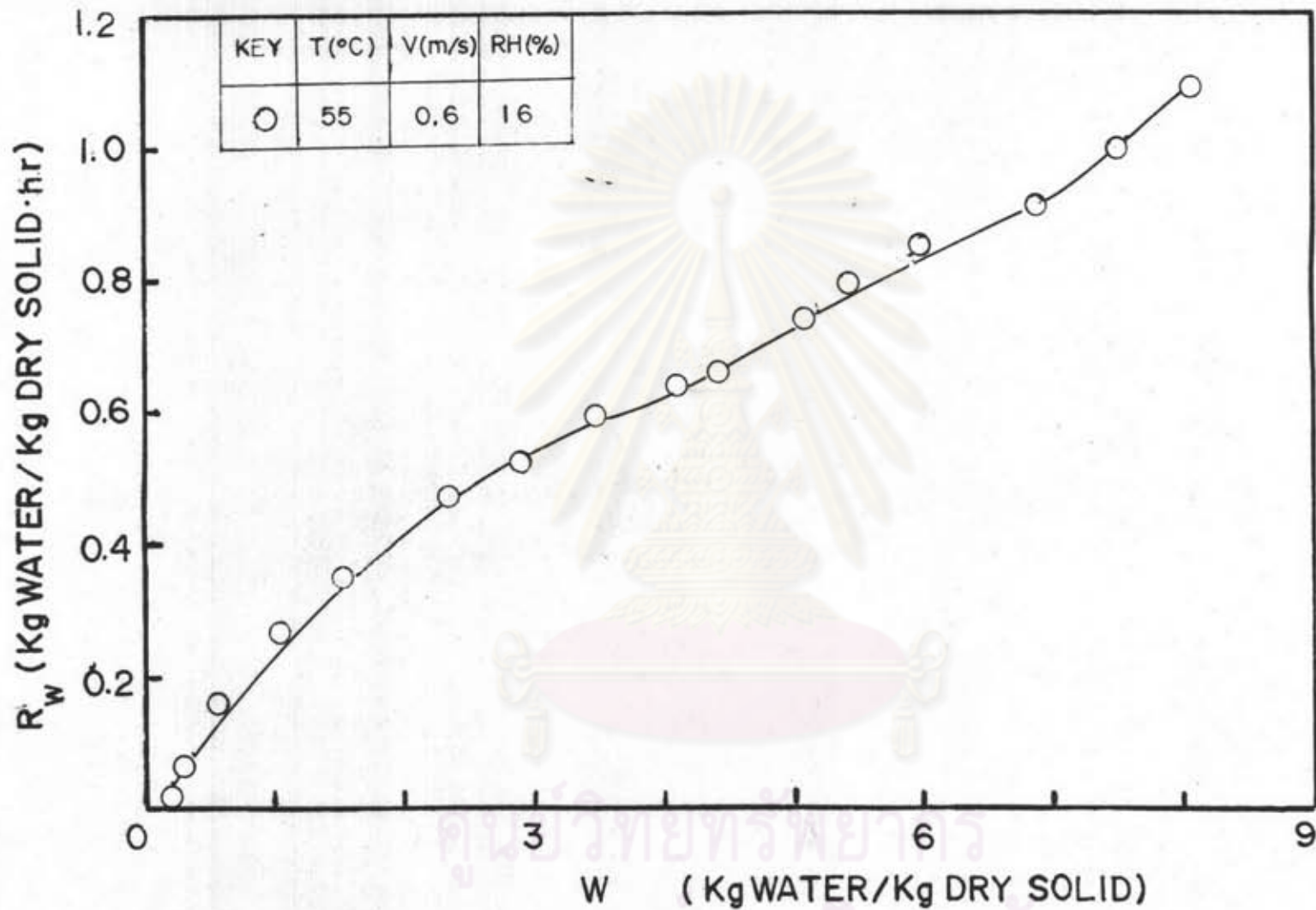


FIG. 4.28 DRYING CHARACTERISTIC CURVE OF STAR-GOOSEBERRY



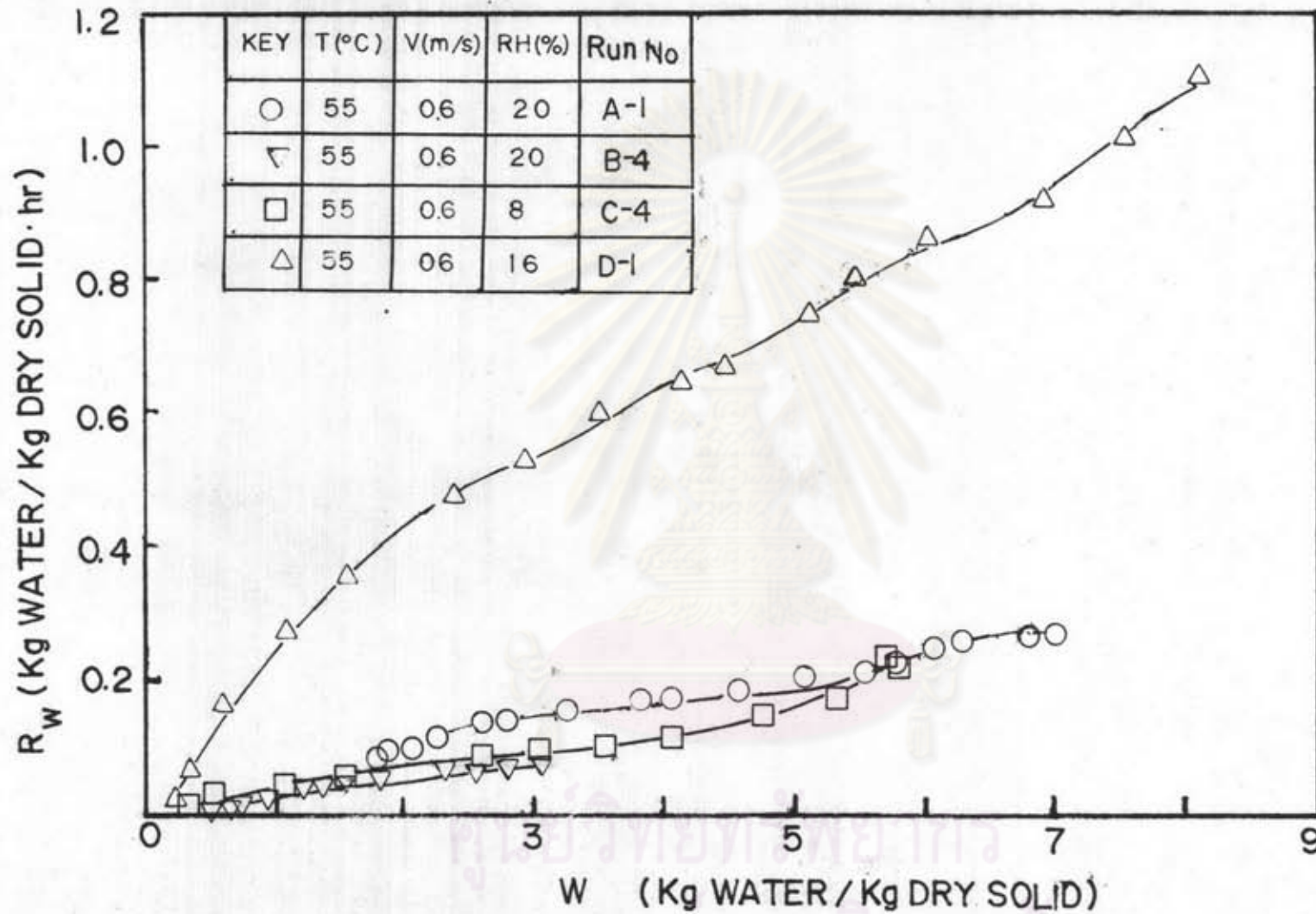


FIG. 4.29 COMPARISON OF DRYING CHARACTERISTIC CURVES

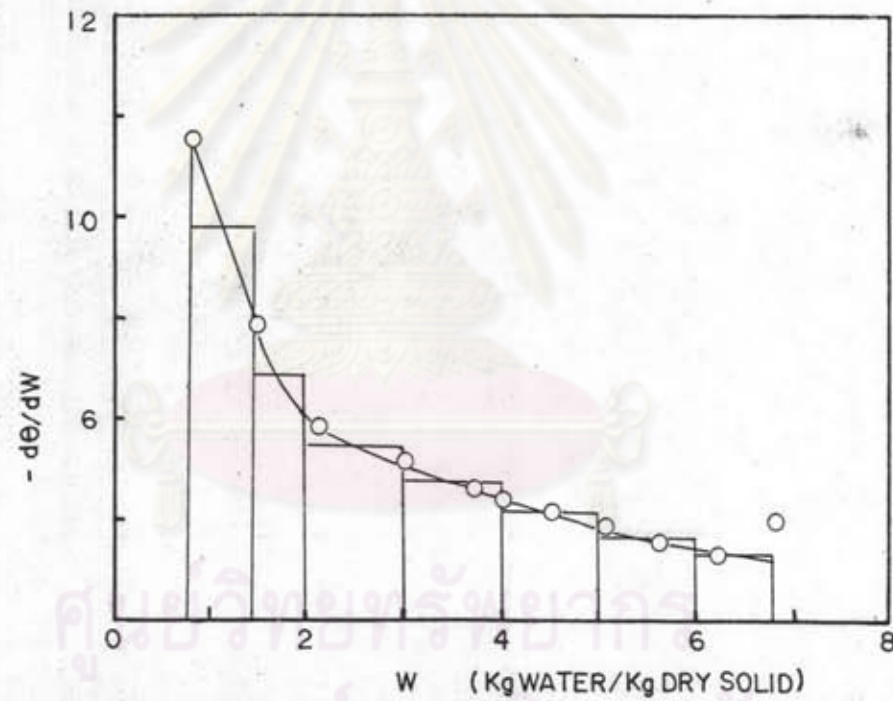


FIG.4.30 RECIPROCAL DRYING RATE VS. MOISTURE CONTENT FOR JUJUBE

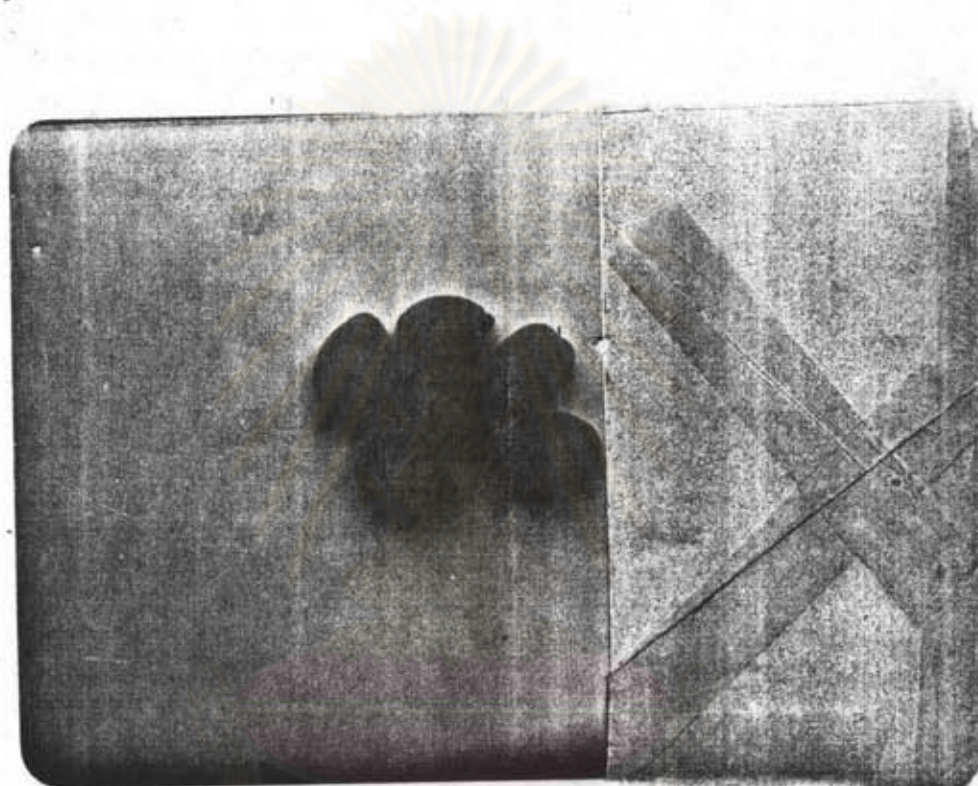


FIGURE 4.31 SAMPLE OF FRESH JUJUBE

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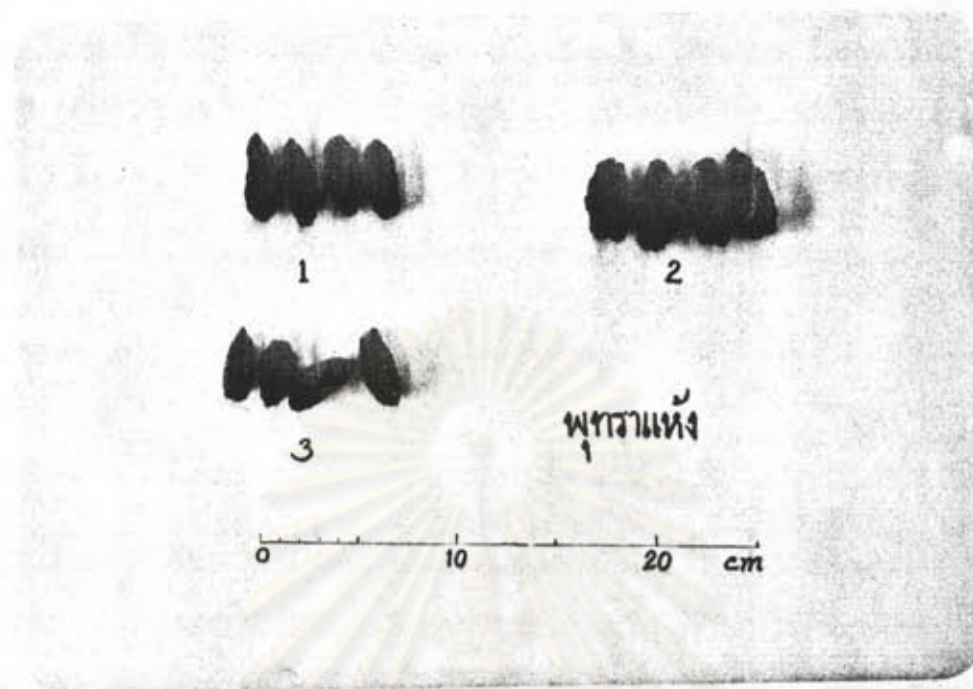


FIGURE 4.32 SAMPLE OF DRIED JUJUBE

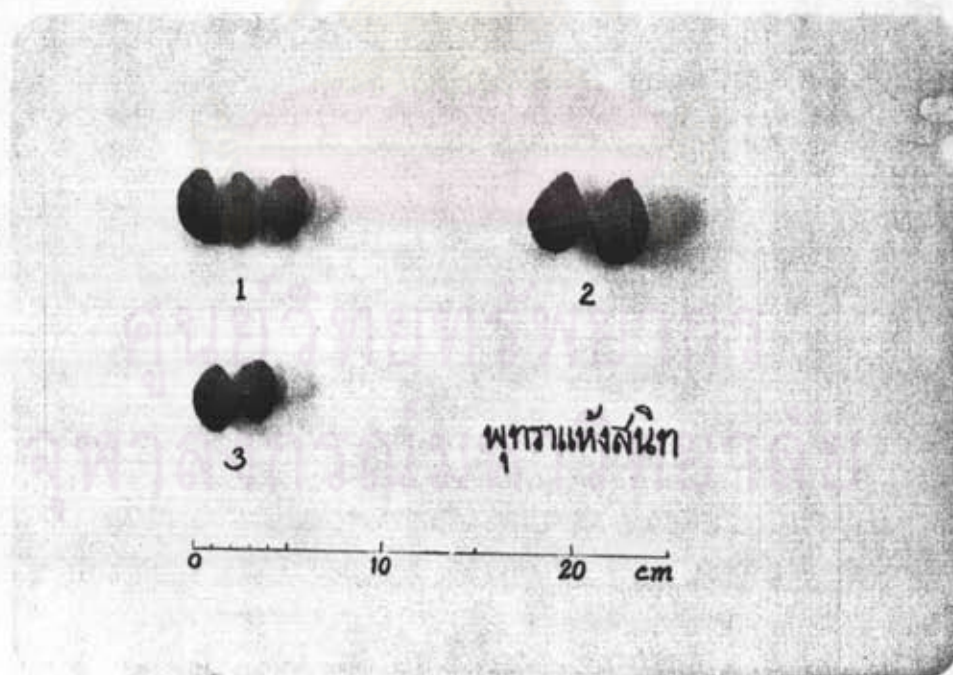


FIGURE 4.33 SAMPLE OF BONE DRY JUJUBE



FIGURE 4.34 SAMPLE OF FRESH SAPOTA

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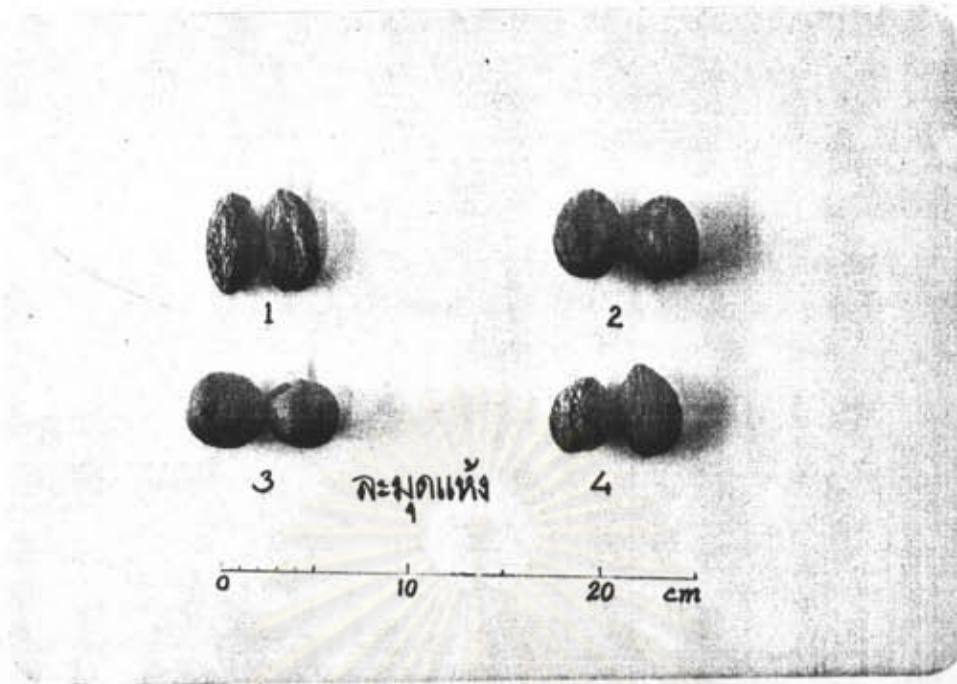


FIGURE 4.35 SAMPLE OF DRIED SAPOTA

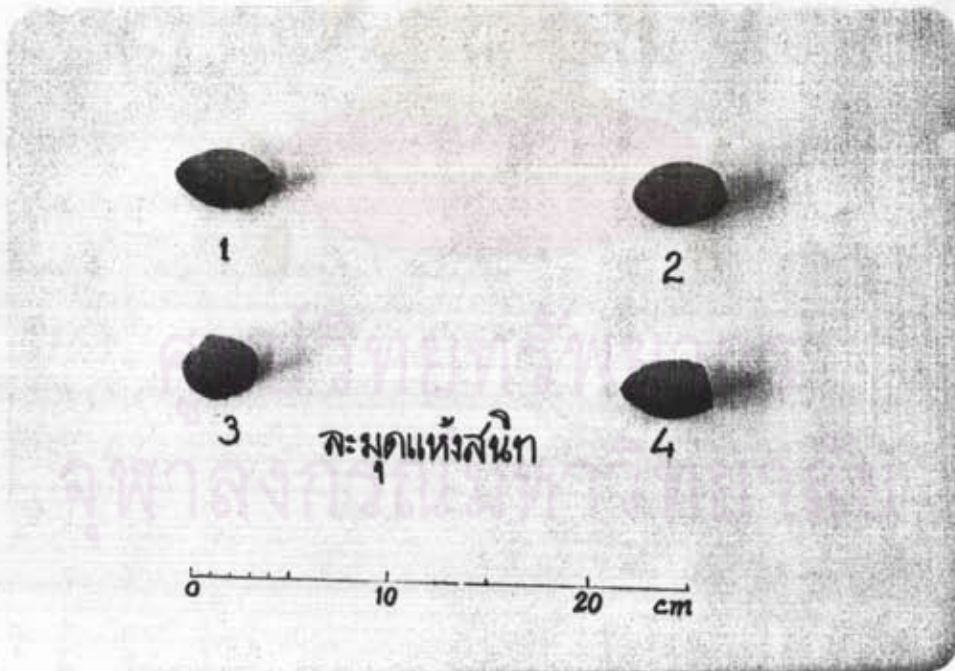


FIGURE 4.36 SAMPLE OF BONE DRY SAPOTA





FIGURE 4.37 SAMPLE OF FRESH GRAPE

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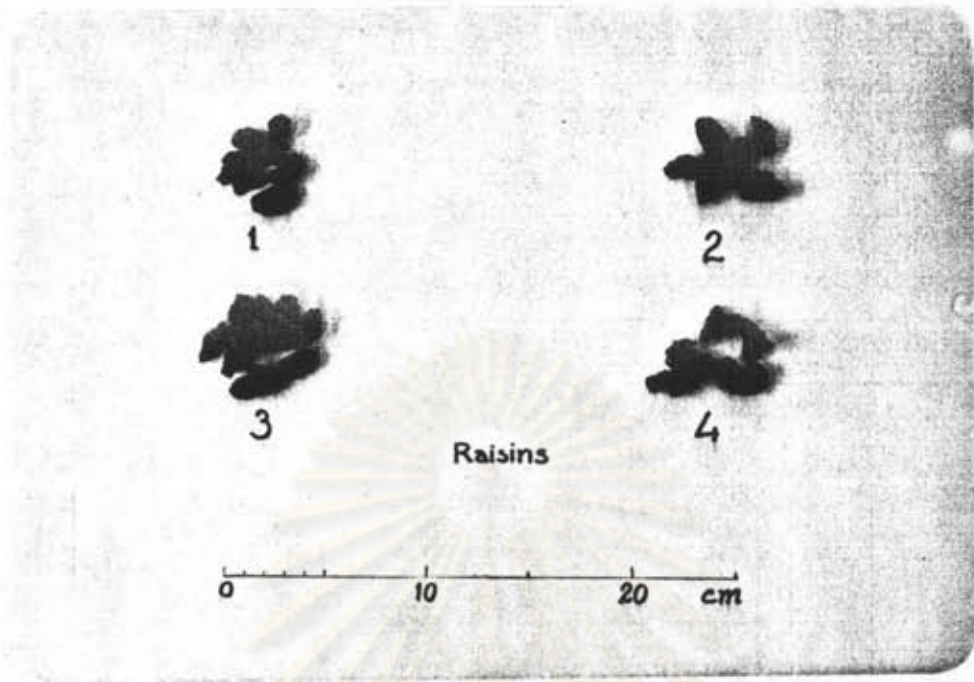


FIGURE 4.38 SAMPLE OF RAISIN

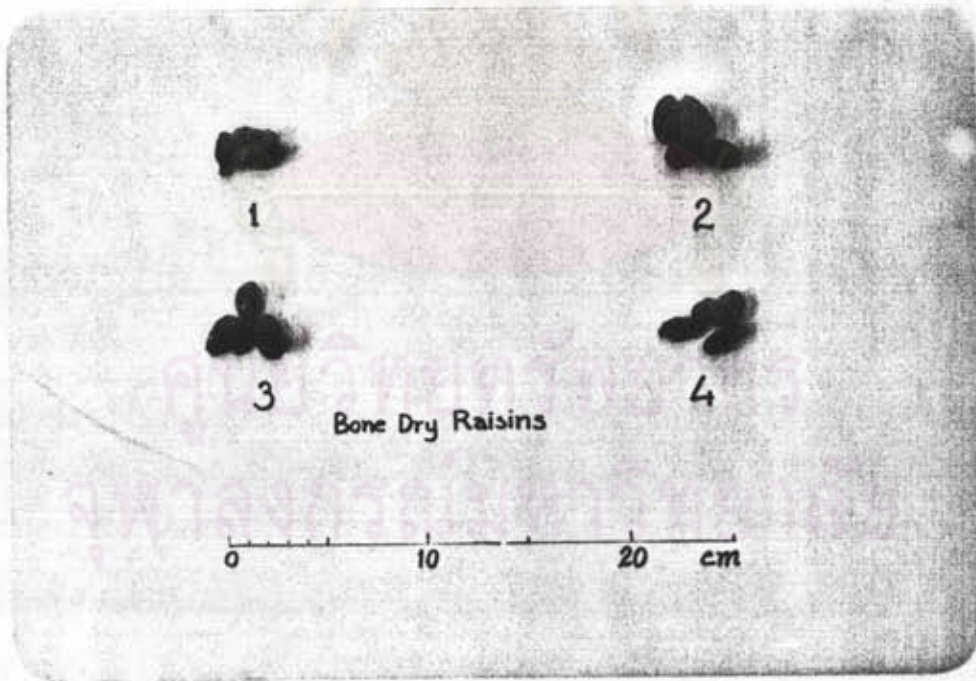


FIGURE 4.39 SAMPLE OF BONE DRY RAISIN



FIGURE 4,40 SAMPLE OF FRESH STAR-GOOSEBERRY

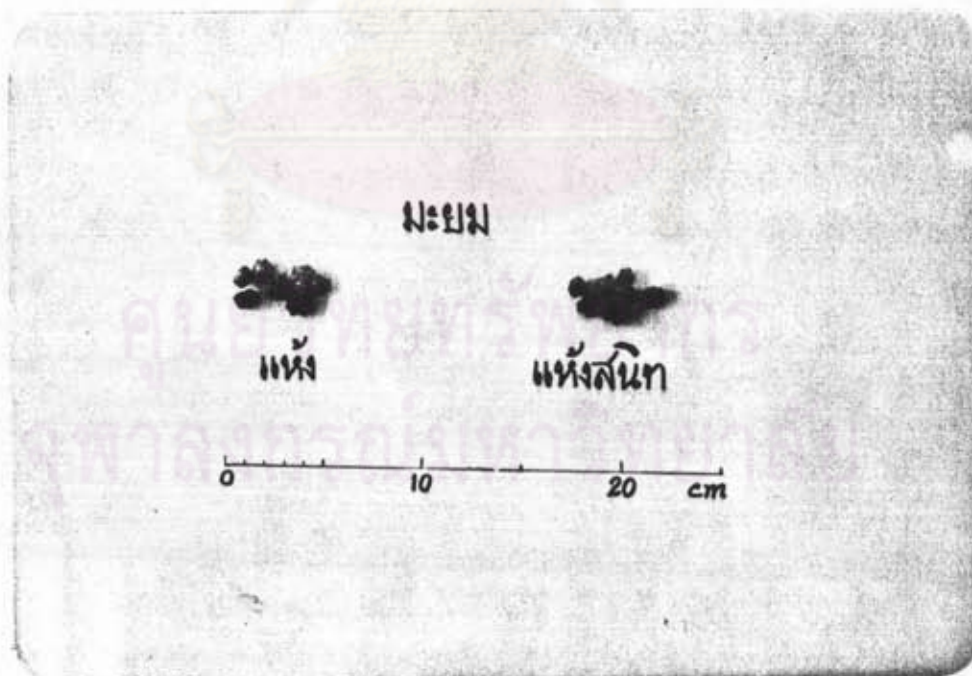


FIGURE 4,41 SAMPLE OF DRIED AND BONE DRY STAR-GOOSEBERRY