

## Drying Characteristics of Minced Fish on Drum Dryers

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### Abstract

The effects of drum spacing, steam pressure and drum speed on drying rate of minced fish flesh on both single and double drum dryers were studied. Starch additions in the form of tapioca flour up to 2.5% have been found satisfactory for aiding in sheet formation at the doctor blade. When the retention time was adjusted to maintain a constant product moisture, the highest production rate was obtained at the smallest drum spacing and the highest steam pressure within the limits of experimental conditions considered. The operating conditions suitable for producing the flakes with 5% moisture were: 100 kPa (steam pressure), 0.1 mm (drum spacing) and 3 rpm (drum speed). The production rate and overall heat transfer coefficient under these conditions were  $12.1 \text{ kg/m}^2\text{hr}$  and  $950 \text{ W/m}^2\text{K}$  respectively. The drying data were fitted well to the conventional drying model, namely  $MR = A \exp(-k\theta)$ , resulting in the various drying constants depending on the operating conditions.

### Introduction

In view of surplus small size fish, the roller dried fish (RDF) can be an alternative to bridge the gap between underutilization and maximum nutritional benefit from the fishing industry. The instant RDF was developed on a pilot plant scale at the Institute of Food Research and Product Development of Kasetsart University in Thailand<sup>(1)</sup>. A cost analysis for the pilot plant production of RDF based on the prices prevailing in Thailand during 1983/84 was carried out with the aid of computer.<sup>(2)</sup>

There have been several papers on drum drying of both raw and precooked fish on a laboratory scale<sup>(3,4)</sup>. Effects of some operating variables and additives on drum drying have also been reported by Jacobsen<sup>(5)</sup> and Nielsen<sup>(6)</sup> respectively.

This paper gives some general information about the factors affecting the drying rate of minced fish flesh on both single and double drum dryers.

### Experiment

#### Raw material

The fish used for this study were *thread fin bream* ranging from 15 to 20 cm in length. They were first headed and eviscerated by hand. After being cleaned, the fish were fed into a deboner (Bibun Deboner model

SD13, Japan). The minced flesh discharged from the deboner was then stored at  $-28^\circ\text{C}$  for several months. Prior to drum drying, it was allowed to thaw gradually at room temperature.

Starch powder was mixed with the minced flesh as it allowed the flesh to adhere better to the rotating drums by reducing the relative oil contents. The starch used was tapioca flour with varying percentages (2.5, 5 and 10%) to determine the minimum amount of starch required without disturbing the drying pattern.

#### Procedure

The majority of experiments were carried out using a double drum dryer made by a local manufacturer with a total drying surface of  $0.4 \text{ m}^2$ . A single drum dryer with a total drying surface of  $2.5 \text{ m}^2$  (Escher Wyss model ES/A255, West Germany) was also used for comparison. The steady state drying conditions were first to be established before drying data were collected. The desired drying temperature was obtained by gradually raising the steam pressure within the drums. Heating continued at this temperature for 30 minutes and then the drums stopped rotating for adjusting the spacing between two drums. After the drums were rerotated, the minced fish flesh was fed to the dryer. It took about 20 minutes to attain the steady state operation. Once the steady state drying conditions were established, flakes

(RDF) were collected from the drums. Subsequently a change in one of the operating variables was made for the different drying conditions. The dryer was then allowed to reach the steady state again and thereafter a different batch of RDF was collected as final products. Similar procedure was applied to a single drum dryer. However, due to the differences in the limitation of two dryers, the same operating conditions could not be set. Table 1 lists the experimental variables studied.

**Results and Discussion**

**Effects of starch**

As shown in Fig. 1, the starch had no considerable influence on drying except lowering the relative moisture content without disturbing the drying pattern. The higher the starch content, the faster the drying rate. However, it was found out that, from the organoleptic point of view, the best product was obtained by adding 2.5% starch to the minced fish flesh.

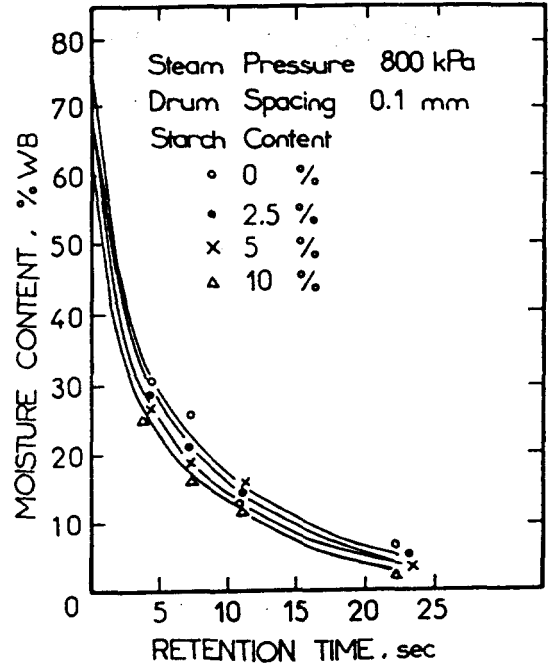
**Effects of operating variables**

• Drum spacing

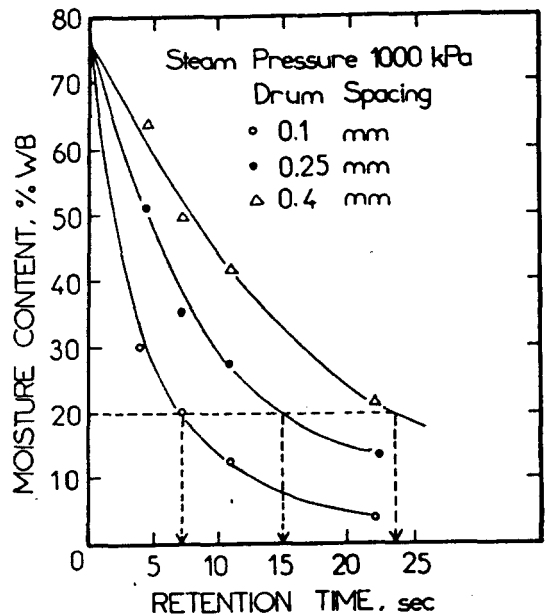
Drum spacing has a significant effect on both product moisture and production rate of dry solid as illustrated in Fig. 2 and 3 respectively. The production rate of dry solid is expressed as the dry weight of product per drying time per drum surface area. The increase in drum spacing resulted in higher moisture content of product and lowered drying rate because of the increase in the thickness of film adhered to the drum surface. The average film thickness increased with increasing drum spacing, as shown in Fig. 4.

**Table 1. Ranges of experimental variables**

Variable	Drum Dryer	
	Single	Double
Drum		
Speed (rpm)	3.7, 6.4, 8.7 11.8, 22.4	1.8, 3.6 5.5, 8.8
Spacing (mm)	0.05	0.1, 0.25, 0.4
Steam Pressure (kPa × 10 <sup>2</sup> )	3, 4, 5 6, 7, 8	7, 8, 10



**Fig. 1. Effect of starch on drying curve of RDF dried on a double drum dryer**



**Fig. 2. Effect of retention time and drum spacing on moisture content of product dried on a double drum dryer**

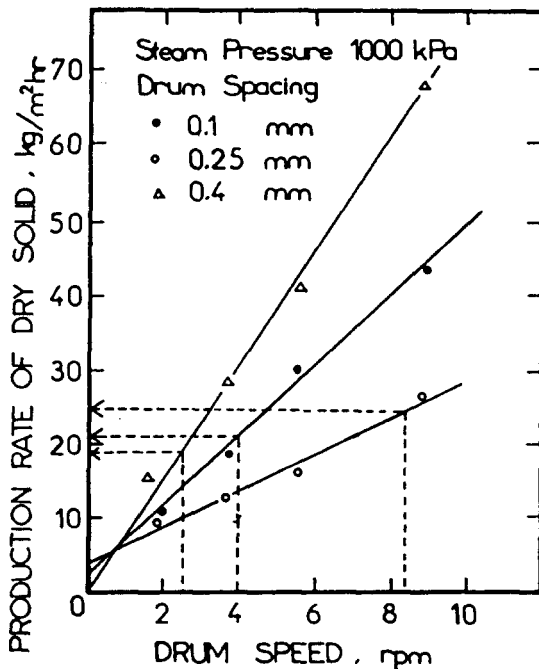


Fig. 3. Effect of drum speed and drum spacing on production rate of dry solid

Average film thickness was calculated based on the following formula<sup>(2)</sup>:

$$L = \frac{RX_f}{C\rho V X_i} \quad (1)$$

where,  $L$  = average film thickness,  $m$   
 $R$  = production rate,  $kg\ RDF/hr$   
 $C$  = drum length  $0.457m$   
 $\rho$  = fish flesh density,  $1080\ kg/m^3$   
 $V$  = tangential drum velocity,  $m/hr$   
 $X_i$  = initial total solids content,  $22\%$   
 $X_f$  = final total solids content,  $\%$

It can be reasoned that the production rate could be increased by increasing drum spacing which would in turn result in increased production rate of dry solid. However, the production rate of dry solid was actually maximized by minimizing the drum spacing while maintaining a constant product moisture. For example, as shown in Fig. 2, at a moisture content of 20 percent the retention time for a drum spacing of  $0.1mm$  was 7.25 sec, i.e., a drum speed of 8.3 rpm. The production rate of dry solid was correspondingly  $24.5kg/m^2\ hr$  (see Fig. 3). At the same moisture content, the production rates of dry solid of 21.5 and  $19.5kg/m^2\ hr$  were obtained for the

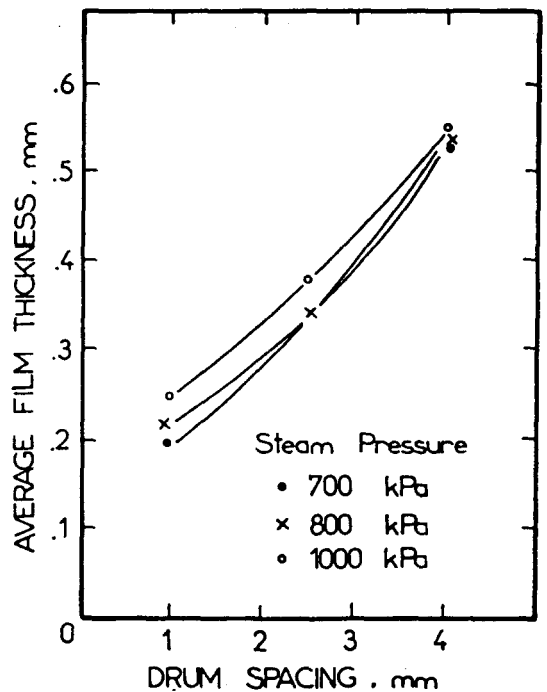


Fig. 4. Effect of drum spacing on film thickness at various steam pressures

drum spacing of 0.25 and  $0.4mm$ , respectively.

A factor which limited the minimum drum spacing used was the peripheral tolerance of the drum, reflecting manufacturing limitations and wear. As the drums were moved closer each other, the uneven spacing due to this tolerance constituted large percentage of the total spacing, which led to appreciable variations in the film thickness. The retention time had to be adjusted so as to dry the thickest portion of the film causing the thin portions to be overdried.

- Drum speed

As shown in Fig. 3, the production rate of dry solid (PR,  $kg/m^2hr$ ) is directly proportional to the drum speed ( $N$ , rpm) as expressed in the following equation:

$$PR = A'N + B' \quad (2)$$

in which  $A'$  and  $B'$  are constants. The values of  $A'$  and  $B'$  are given in Table 2 together with the correlation coefficients. As seen in Table 2, the proportionality constant  $A'$  increases with the drum spacing indicating that the effect of drum speed is more pronounced at the larger drum spacing.

- Steam pressure

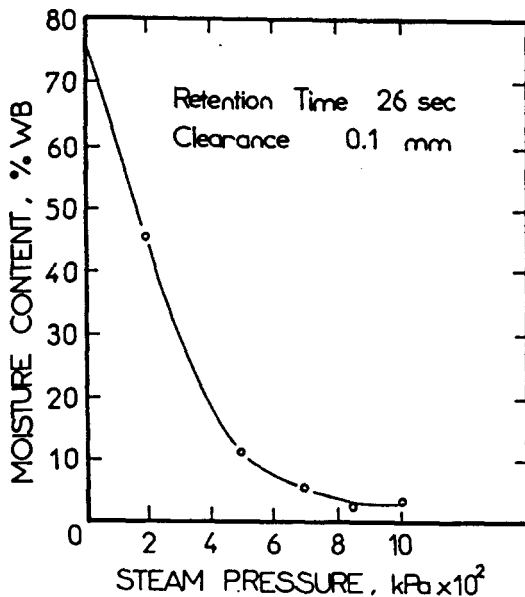
The product moisture obviously decreased with increase in the steam pressure due to the higher drum sur-

**Table 2. Values of constants for the relationship between production rate of dry solid and drum speed at various operating conditions**

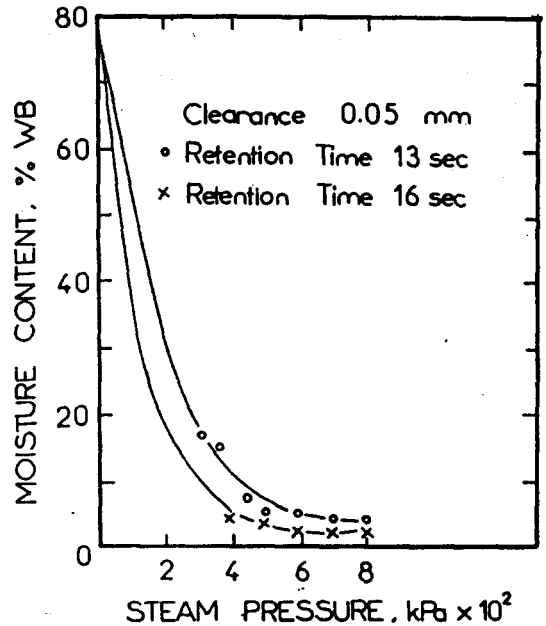
Steam Pressure (kPa × 10 <sup>2</sup> )	Drum Spacing (mm)	A'	B'	r
7	0.1	1.8	3.72	0.993
7	0.25	4.0	3.14	0.993
7	0.4	7.4	1.59	0.999
8	0.1	2.5	1.94	0.985
8	0.25	4.6	1.04	0.999
8	0.4	6.1	6.0	0.992
10	0.1	2.5	3.83	0.995
10	0.25	4.7	2.47	0.997
10	0.4	7.7	0.26	0.999

face temperature at the higher steam pressure which in turn induced the larger heat transfer driving force (see Fig. 5 and 6).

Unlike the product moisture, the production rate of dry solid was affected to a lesser extent by the steam pressure as the A' values did not vary considerably with the steam pressure at a constant drum spacing (see Table 2). However, at the same moisture content of the product, the higher production rate of dry solid was obtained at the higher steam pressure. For example, at the product moisture of 20 percent and drum spacing of 0.1mm, the



**Fig. 5. Effect of steam pressure on moisture content of product dried on a double drum dryer**



**Fig. 6. Effect of steam pressure on moisture content of product dried on a single drum dryer**

production rates of dry solid at 700, 800 and 1000 kPa were 12.5, 18.5, and 24.5kg/m<sup>2</sup> hr, respectively. Nevertheless, there was a limit for the maximum steam pressure that could be applied. Too high a pressure could result in either scorching of the product or producing rough film because the heated fish flesh would not be properly attached to the drum at the excessively high surface temperature.

**Overall heat transfer coefficient**

The procedure of calculating the overall heat transfer coefficient was described in detail elsewhere.<sup>(2)</sup> As in the case of the production rate of dry solid, the overall heat transfer coefficient (U) increased with the drum speed since the U values were determined based on the evaporation rate (see Fig. 7). It should be noted that the larger drum spacing resulted in the higher residual moisture content of the product at a constant drum speed. Therefore, the U values at a constant product moisture did not increase with the drum spacing as it appeared in Fig. 7.

**Drying model**

In order to compare the drying curves, moisture content was changed to moisture ratio defined as:

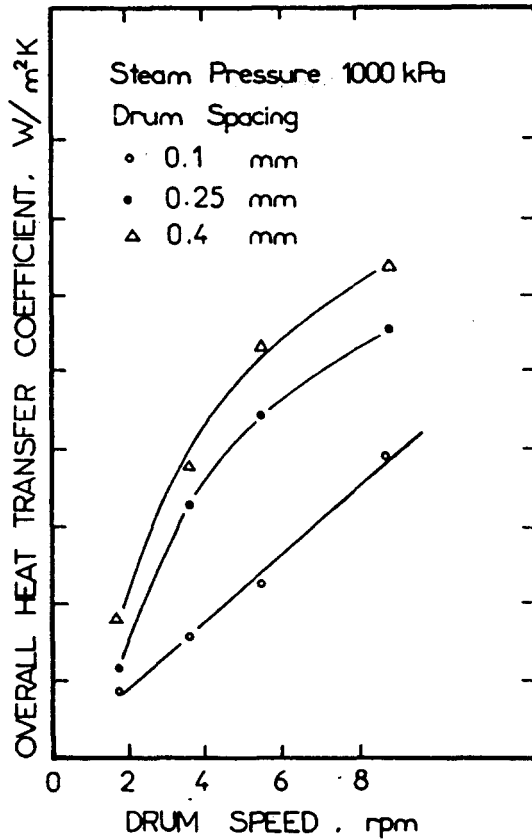


Fig. 7. Effect of drum speed on overall heat transfer coefficient

$$MR = \frac{M - M_e}{M_o - M_e} \quad (3)$$

where, MR = moisture ratio

M = moisture content (wet basis) at any retention time, %

M<sub>o</sub> = initial moisture content (wet basis), 78%

M<sub>e</sub> = equilibrium moisture content, %

Moisture ratio of a thin film of product can be described by the equation (4):

$$MR = Ae^{-k\theta} \quad (4)$$

where,  $\theta$  = retention time, sec

A k = constants

By trial and error, a value of equilibrium moisture content was assumed and the corresponding moisture ratio was plotted against the retention time on a semi-log paper until the best straight line was obtained using the

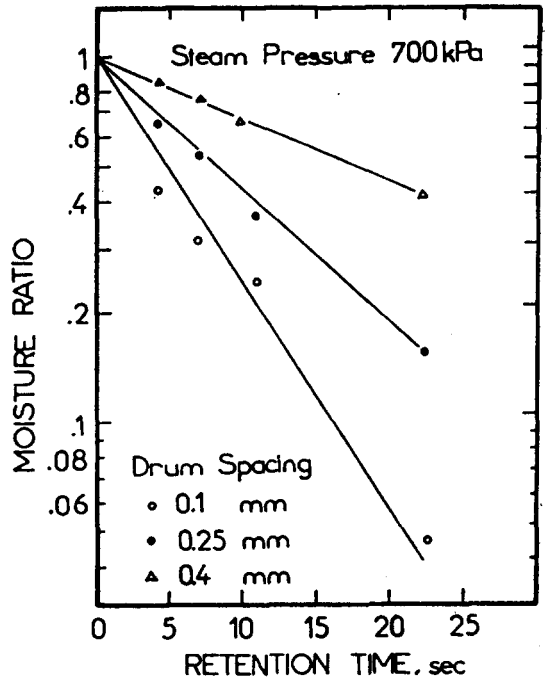


Fig. 8. Moisture ratios as a function of retention time

least mean square method (see Fig. 8). Five percent was found to be the correct equilibrium moisture content. The constant A was determined to be unity from the initial condition and the various drying constants(k) were obtained from the slopes depending on the operating conditions (see Table 3).

### Nomenclature

A = constant

Table 3. Drying constants under the various operating conditions

Steam Pressure (kPa × 10 <sup>2</sup> )	Drum Spacing (mm)	k	r
7	0.1	0.06	0.994
7	0.25	0.04	0.998
7	0.4	0.02	0.998
8	0.1	0.08	0.997
8	0.25	0.04	0.997
8	0.4	0.02	0.998
10	0.1	0.10	0.998
10	0.25	0.05	0.991
10	0.4	0.03	0.997

**A'** = constant  
**B'** = constant  
**C** = drum length, 0.457m  
**k** = drying constant  
**L** = average film thickness, m  
**M** = moisture content (wet basis) at any retention time, %  
**M<sub>e</sub>** = equilibrium moisture content (wet basis), %  
**M<sub>0</sub>** = initial moisture content (wet basis), 78%  
**MR** = moisture ratio  
**N** = drum speed, rpm,  
**PR** = production rate of dry solid, kg/m<sup>2</sup>hr  
**r** = correlation coefficient  
**R** = production rate, kg RDF/hr  
**X<sub>f</sub>** = final total solids content, %  
**X<sub>i</sub>** = initial total solids content, 22%  
**U** = overall heat transfer coefficient, W/m<sup>2</sup> K  
**V** = tangential drum velocity, m/hr  
**θ** = retention time, sec

**ρ** = fish flesh density, 1080 kg/m<sup>3</sup>

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## 잘게 저민 생선의 드럼건조기에 의한 건조특성

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단원통형 및 복원통형 드럼건조기를 이용하여 잘게 저민 생선으로부터 플레이크를 성공적으로 만들 수 있었다. 생선의 높은 지방함량으로 인해 저민 생선이 드럼에 잘 들러붙지 않는 문제점은 타피오카가루의 형태로 2.5%의 전분을 저민 생선에 첨가함으로써 건조양상에는 영향을 미치지 않으면서 해결될 수 있었다.

제품의 수분함량을 일정한 수준으로 유지할 경우 乾固形分の 생산속도는 드럼간의 간격을 최소로 줄였을 때 최

고에 도달하였다. 乾固形分の 생산속도는 드럼의 회전속도가 증가할수록 선형적으로 증가하였고 제품의 품질이 손상되지 않는 범위에서 스팀의 압력이 높을수록 증가하였다. 총괄 열전달계수는 드럼의 회전수가 증가함에 따라 증가한 반면에 드럼간의 간격이 커짐에 따라 증가하지는 않았다.  $MR = A \exp(-k\theta)$ 로 표시되는 가장 보편적인 건조 모델식이 드럼건조에도 적용될 수 있었다.