

DRYING PARAMETERS OF PLANT-FISH FEEDING CONCENTRATES IN DRUM DRIERS*

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A b s t r a c t. Lack of literature data relating to the parameters of drying the plant-fish feedstuffs in industrial hot-air and contact drum driers was the reason for undertaking this research. Its purpose was to determine the relationship between the input parameters of the drying operation and the dry weight content in plant-fish feeding concentrates. The knowledge of this relationship is a necessary condition for a conscious control of the drying operation of such concentrates in the industrial conditions. In the tests, mashes were dried at a ratio of 3:1 (fish component: plant component, by weight), based on feed sprat preliminary ground to the particles equivalent in diameter to 3.5 mm, and wheat bran. For the changing sets of the values of the input parameters (temperature, time, filling degree of the drum with the mash, drum circumferential velocity and air flow velocity), the dry weight content was determined in the product. The results obtained allowed for the formulation of the relationship between the dry weight content in the product as a function of drying parameters grouped into dimensionless numbers.

Key words: drying, fish, plant, concentrate

INTRODUCTION

Plant-fish feeding concentrates, i.e. a dried mixture of cereal waste products (e.g., wheat bran, oilseed cakes) and fish waste products, are a technological variety of meat bone meals. They are a relatively new assortment on the feedstuffs market, attractive due to the enrichment of the plant feed with animal protein.

The production of plant-fish feeding mashes is conducted on adapted production lines that so far were used for the drying of green forages and cereal feedstuffs. According to the best know-

ledge of the present author the main elements of these lines, are the van den Brock drum driers. Even though the technical and working parameters of these driers make it possible to obtain a product satisfying customers' requirements, they are not necessarily optimal for the drying process of plant-fish mashes. To achieve analytical optimization determining the diffusion coefficient of plant-fish mashes is required. However, even determination of this coefficient does not ensure selection of the parameters of the drying operation. This stems from the fact that drying in drum driers is a complicated process, and all the computations are difficult and rather inaccurate [2]. Therefore, in order to determine the variation in the dry weight content of the dried product during the drying process and to test the possibility of drying plant-fish mashes in other types of drum driers used in the farm-food processing, appropriate model tests have been conducted.

MATERIALS

For the drying of farm and food waste products - similar in consistency to plant-fish mashes, hot-air and contact drum driers are used in the industrial practice [1,2]. A conscious control of the drying operation in drum driers requires the knowledge of the relationship describing changes in the dry weight content of the

product during the drying operation. Tests were performed by drying a mash prepared at a ratio of 3:1 (by weight) from wheat bran and ground feed sprat in the model drum driers.

The lay-out of the test stand on which the tests were performed are shown in Figs 1 and 2. Its principal element is the rotary drum with the diameter $d=100$ mm. Revolutions of the drum can be adjusted with a frequency converter.

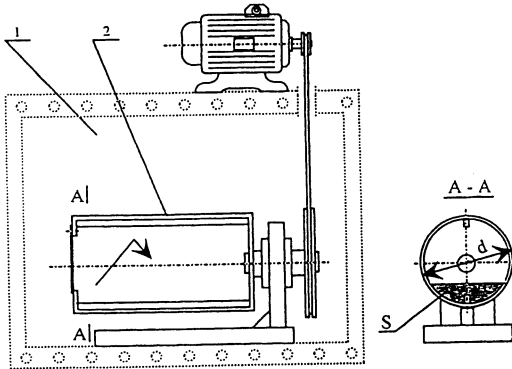


Fig. 1. Lay-out of the test stand for the determination of drying parameters in the contact bin dryer: 1 - laboratory dryer, 2 - bin, S - cross section area of the material filling the bin.

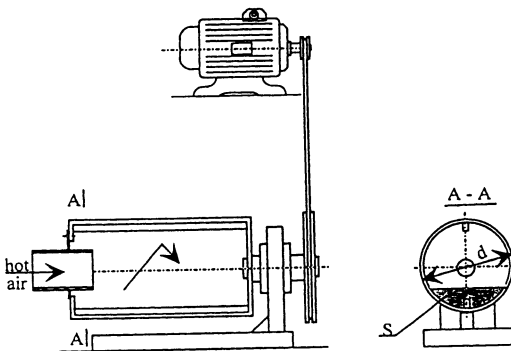


Fig. 2. Lay-out of the test stand for the determination of drying parameters in the hot-air bin drier.

The input parameters of the drying operation in the contact drum dryer are as follows: circumferential velocity of material transportation v_o in the drum (drum circumferential velocity), drying temperature T , drying time t , filling degree of the drum with material ϕ , consistency of material, and the output parameter is the dry weight m_d of the product.

In the case of drying in the convectional drum dryer, the additional input parameter is air flow velocity in the drum v_a .

Preliminary tests made it possible to determine one input parameter - the consistency of the material. It turned out that overgrinding of the raw material results in its sticking together during drum revolutions. The portion of the material stuck together, dried on the outside, and did not dry properly inside. Therefore, in the further tests, a degree of fineness defined as thickly ground was used. The equivalent diameter of particles of ground fish in this case is $d_e=3.5$ mm. For a limited number of input parameters of the drying operation, based on the Box-Behnken plan of tests [3], a series of measurements were taken, assuming the following range of variability of input parameters:

a) in the contact drying tests:

- drying time, $t \in [1800; 3000]$, [s];
- drum circumferential velocity, $v_b \in [0.03; 0.06]$, [$m \cdot s^{-1}$];
- filling degree of the drum, $\phi \in [0.05; 0.20]$, [-];
- drying temperature, $T \in [120; 160]$, [$^{\circ}C$];

b) in convectional drying tests:

- drying time, $t \in [1200; 2400]$, [s];
- drum circumferential velocity, $v_b \in [0.03; 0.12]$, [$m \cdot s^{-1}$];
- air flow velocity in the drum (RH of air - 10%), $v_a \in [1.5; 2.5]$, [$m \cdot s^{-1}$];
- filling degree of the drum, $\phi \in [0.05; 0.20]$, [-];
- drying temperature, $T \in [105; 175]$, [$^{\circ}C$].

RESULTS AND DISCUSSION

After taking measurements, input parameters were grouped into dimensionless numbers by using dimensional analysis which facilitated passing from the model scale to the real scale:

- for contact drying:

$$P_1 = \frac{v_b t}{\left(\frac{s}{d}\right)} \quad (1)$$

- for the convectonal drying:

$$P_2 = \frac{v_b v_a t^2}{\left(\frac{s}{d}\right)^2} \quad (2)$$

- Fourier number for both types of drying:

$$F_o = \frac{at}{d_e^2} \quad (3)$$

and the area of the cross section of the product filling the drum drier:

$$S = \frac{\pi d^2 \phi}{4}$$

were d is diameter of the drum, d_e - equivalent diameter of the raw material, a - water diffusivity analogical to the thermal diffusivity in hot transfer.

Since water diffusivity changes during the drying process along with an increase in the temperature, we assumed:

$$a = a_o \exp\left(-\frac{c}{T}\right) \quad (4)$$

where c is the constant characteristic of a given raw material. After inserting (4) into (3), the following was obtained:

$$F_{o1} = \frac{t a_o \exp\left(-\frac{c}{T}\right)}{d_e^2} \quad (5)$$

As a_o and d_s are constants for the given raw material, $\left(\frac{a_o}{d_e^2}\right) = c_1$ was inserted into (5), to give:

$$F_{o2} = c_1 t \exp\left(-\frac{c}{T}\right) \quad (6)$$

For thus determined dimensionless numbers, the corresponding values of the input parameters of the respective points in the experiments were grouped. They underwent statistical processing, together with the corresponding values of dry weight (see Tables 1 and 2) to give the following functions:

- for the contact drying:

$$m_d = 0.13 P_1^{0.054} F_{o2}^{0.278} \quad (7)$$

where $F_{o2} = 0.517 t \exp\left(-\frac{413.241}{T}\right) \quad (8)$

Table 1. Experimental results of the contact drying

P_1	F_{o2}	m_d
$\frac{v_b t}{\left(\frac{s}{d}\right)}$	$0.517 t \exp\left(-\frac{413.241}{T}\right)$	-
24000	49.5499	0.719
14400	29.7299	0.639
12000	49.5499	0.681
7200	29.7299	0.584
48000	49.5499	0.575
28800	29.7299	0.506
24000	49.5499	0.628
28800	29.7299	0.567
19200	39.6399	0.622
9600	46.8808	0.595
24000	117.202	0.780
14400	70.3212	0.685
12000	117.202	0.791
48000	117.202	0.802
28800	70.3212	0.800
24000	117.202	0.728
14400	70.3212	0.717
48000	117.202	0.902
28800	70.3212	0.757
12000	117.202	0.869
7200	70.3212	0.762
24000	117.202	0.861
14400	70.3212	0.641
24000	117.202	0.822
14400	70.3212	0.619
14400	93.7616	0.768
28800	93.7616	0.925
25600	93.7616	0.910
12800	93.7616	0.804
4800	70.3212	0.568
3600	70.3212	0.601
6000	117.202	0.792

Table 2. Experimental results of the convective drying

P_2	Fo_2	m_d
$\frac{v_b v_a t^2}{\left(\frac{s}{d}\right)^2}$	$0.000406 t \exp\left(-\frac{296.2}{T}\right)$	-
4.40842e+009	0.0300243	0.871
1.83586e+009	0.0915307	0.902
7.34345e+009	0.0600487	0.840
1.83586e+009	0.183061	0.928
4.40842e+009	0.183061	0.916
1.17495e+011	0.183061	0.978
1.76337e+010	0.183061	0.954
7.05347e+010	0.0600487	0.863
2.93738e+010	0.0600487	0.905
1.1021e+009	0.0600487	0.749
1.76337e+010	0.0915307	0.863
7.34345e+009	0.0915307	0.935
2.75226e+008	0.0915307	0.767
2.93738e+010	0.0300243	0.827
1.1021e+009	0.0300243	0.541
4.58966e+008	0.0300243	0.601
6.27902e+009	0.120521	0.838
3.53195e+009	0.137296	0.887
7.04147e+009	0.0903906	0.786
4.90396e+009	0.0903906	0.960
1.49225e+009	0.0903906	0.729

- for the convective drying:

$$m_d = 0.503P_2^{0.037}Fo_2^{0.127} \quad (9)$$

where $Fo_2 = 0.000406 t \exp\left(-\frac{292.6}{T}\right)$. (10)

For the derived function (7), $R^2 = 99.24\%$ and the Mean Absolute Error = 0.053, and for the function (9), $R^2 = 99.34\%$ and the Mean Absolute Error = 0.054.

The functions $m_d = f(P, Fo_2)$, graphically presented in Figs 3 and 4, make it possible to control the drying operation and its optimization with regard to the criterion adopted.

CONCLUSIONS

The results obtained in the tests make it possible to draw the following conclusions:

- it is possible to dry plant-fish feeding meshes in hot-air and contact drum driers with a satisfactory efficiency,
- technological and working parameters of the

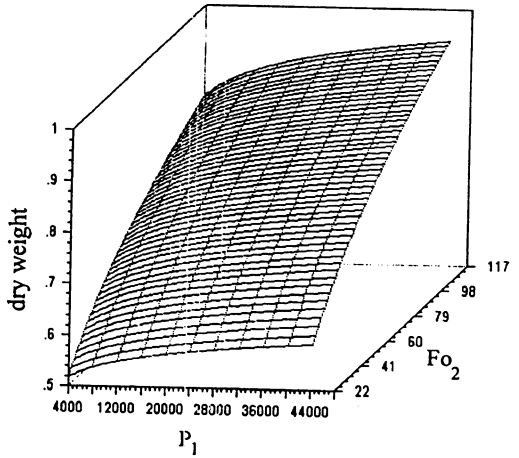


Fig. 3. Relationship $m_d = f(P_1, Fo_2)$ during contact drying.

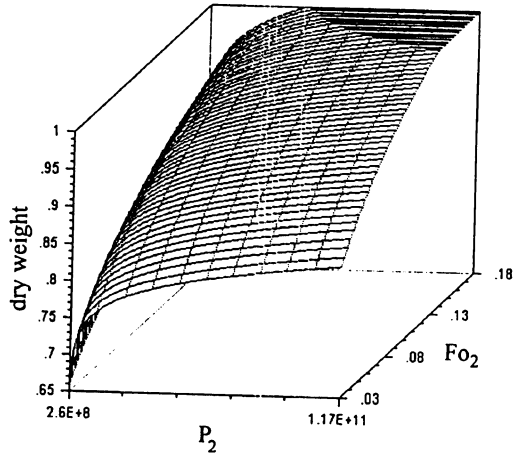


Fig. 4. Relationship $m_d = f(P_2, Fo_2)$ during hot-air drying.

driers which can be used for this purpose do not deviate from those used when drying cereal feedstuffs and green forages,

- adjustment of the degree of fineness of a feeding mash to the type of dryer is a condition for the appropriate progress of the operation,
- even though the results obtained in the tests facilitate manufacture of the product with the specified parameters, in the case of designing new production lines for plant-fish concentrates, the replacement of energy-consuming and large drum driers with extruders should be considered.

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