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An Experimental Analysis and Expertise for a Fish-Drying Process Control

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Abstract

Analysis is made for a fish-drying process control in order to implement a human expertize into an automated fish drying system. Together with the idea described in the companion paper, a methodology is found effective in a general drying system other than fish drying.

1.Introduction

Dried marine products are traditonal foods in Japan which are produced since ancient periods. The principles and techniques are not sufficiently developed in spite of this fact. Most of the manufacturers of these products are not big, and due to this fact together with the severe working circumstance including smells, high temperature and moisture, workers have been continually lacking in this field of manufacturing. So the companies in this field have also been facing the advancing in age of the workers. The automatization for labor-saving may be a solution to these problems. But there are the consumers' preference, the difference between the species of fish and also the difference between individual fish.[1] These issues make it difficult to apply a certain fixed automatic production;i.e., A different way may be applied for a different fish. Fishes depend on the place of fishery, the seasons, the size of the fish, maturity and so on in their components. Individual difference sometimes is one of the major factors. These facts leads to the difference in the finish of products under the same drying condition. So the human skill has been really crucial in producing these products. The empirical intuition of the skilled workers mainly uses qualitative expressions in regulating the drying condition because of the conceptual human way of understanding things. If this sort of human skill is introduced in fish drying systems, then the difficulty mentioned in automating will be eliminated and a good control system will be obtained. The authors performed some organized experiments for extracting the necessary characteristics in proposing such a new automated system for fish drying.

2.Human Special Techniques and Knowledge for the Fish Drying Process

2.1 Analysis of Special Techniques and Knowledge

For the drying of round herring, as the representative salted-dried food, the procedure for drying employed by a human expert at this moment can be largely broken down into the following three steps:
Step 1. Predict the drying time to finish and take fish into the drying room, determining the approapriate drying condition. This step can be achieved by the knowledge of raw fish at the time of catching and also its knowledge right before drying.
Step 2. Carriers with the fish on them are changed their locations in the drying room in order to guarantee equal drying environment to every fish in the room.
Step 3. Check, visually and by fingering (pushing or pinching by finger(s)), the status of the fish in the room one by one when the predicted drying time approaches. Dry it more if necessary.
Thus the drying is completed.

The above steps employed by an expert can be described as the hollistic whole constituted by segmented local knowledge of material (raw fish), drying condition, and the finish as the outcome of the former two factors:
(1) Knowledge on the material
a) The season of fishing and the netting time of fish in the day
The season of fishing affects the size and the component of fish. To be concrete, the amount of fat is different between fishes netted in the evening and in the morning.
b) The place of fishing
The same effect as in a) comes from the difference in the place of fishing.
c) The size of fish

The constitution of fish depends on the size of an individual fish. This leads to the change in drying rate.
d) The constituents of fish
Especially fatness affects the drying time.
e) Freshness
Fresheness affects the finish.
f) Fish preserving condition (freezing)The time length and the condition of preserving fish affects the drying rate and the finish.
(2) Knowledge on drying
a) The drying temperature
The drying rate and the finish depends on the temperature of the air in the drying room.
b) The drying moisture
The drying rate and the finish also depnd on the moisture in the drying room.
c) The wind flow rate
The drying rate depends on the flow rate of the wind applied.
d) The direction of the wind
The drying rate and the finish depend on the orientation of the individual fish in the wind.
e) The location in the drying room
The drying rate and the finish depend on the location of an individual fish in the drying room, the windward or the leeward.
(3) Knowledge on the finish
a) The hardness of the product
The degree of dryness can be estimated by pinching or pushing an individual fish to be tested by finger(s).
b) The appearance of the product
The degree of dryness and the appearance preferable to consumers can be judged by seeing the objective fish.

2-2 Organizing the Techniques and Knowledge for Automating the Process

The description in Section 2-2 makes it possible to extract the factors necessary in controlling the drying process.

(1) Factors related to the raw fish
The flesh components of raw fish include water, protein, fat, carbohydrate, and ash. It is said that these constituents except fat depend largely on the season, the place and the size of the fish caught.[2,3] The authors' analysis of the components of the fish netted off the coast of Yamaguchi Prefecture in the middle of September in 1991 shows the same tendency to prove the appropriateness of the description in these references. Table 1 shows the the result of the analysis together with the data in Reference [1].

Considering about the mechanism of drying shows that the possible components are water and fat, which affect the drying rate. In general, the more water the fish includes, the less fat the fish includes, and vice versa. Hence it may be said that the amount of the water included in the fish body implies the easiness of drying, and that the amount of fat implies, in turn, the difficulty of drying. In fact, the existence of this negative correlation between the amounts of water and fat is shown in Reference [4].

The individual difference in fish for an expert can be recognized as the difference in the size, the weight, and the thickness of fish body. For the fish of the same species, both the weight and the thickness usually increase with the size. The relation between the size and the weight of the fish for the present experiments are shown in Fig.1.

A positive correlation (correlation coefficient=0.79) is found between the size and the weight with respect to the fish of the size from 140mm up to 189mm. The difference in weight among the fish of an equal size is due to the difference in body thickness. Assuming that the drying mechanism is the diffusion of water from inside the body to the surface with the evaporation to the surrounding air leads to the conclusion that the difference in body thickness have some effects on the drying rate.

Table 2 shows the result of the component analysis for the fish from the same group. Table 2 implies that the amount of fat increases with the size; i.e., "the difficulty in drying" increases with the size.

An expert understands the freshness of fish to be one of the decisive factors of the status of finish. He judges the goodness of the finish by the appearance and the hardness of the product. The former index is for the purpose or the kind of the product, and the latter corresponds to the consumers' visual satisfaction. The authors have already examined the relationship between the freshness and the goodness of finish, and the results are partly described in References. This examination is based on the change of the degree of the putrefaction(index:VBN,TMA) and the autolysis(index:K-value) with elapsed time. The result shows that the rates of those progress depend on the original amounts and the degree of the hardness of the product(the amount of water left in the body).
(2)Factors related to the drying condition and the finish

To speak briefly from the viewpoint of constructing an automated expert system, Factors (1) deal with the knowledge that is formed by the accumulation of experiencing for the overall knowledge based on an expert's sensory inspection of the raw fish. He estimates the required drying time and the proper condition for it. For automating the sytem, the introduction of an alternative or an auxiliary idea for his procedure may be effective and

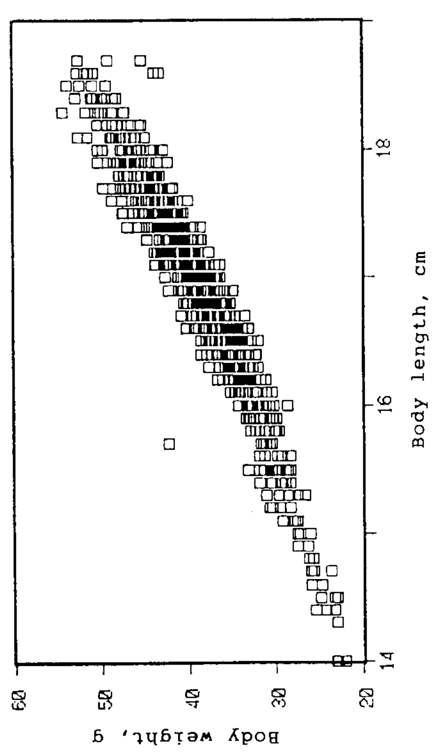
Table 1 Components of raw fish (material)

(per 100g of edible portion; %)

		Water	Protein	Fat	Carbohydrate	Ash
Data in Reference[1]		71.9	21.3	4.6	0.3	1.9
Present Results	Range	67.0 ~ 72.2	19.4 ~ 23.0	2.9 ~ 7.0	0.3 ~ 1.1	2.7 ~ 4.8
	Average	69.7	21.3	4.8	0.6	3.6

Table 2 Difference in components due to fish length (%)

Fish length	Water	Protein	Fat	Carbohydrate	Ash
193mm	70.0	20.7	5.4	0.6	3.3
151mm	71.6	20.7	3.2	0.5	4.0



'''mber of samples = 896

Fig. 1 Relationship betw' weight of round herring

easier to handle the knowledge equivalent to his. Building an automated system does not necessarily mean just mimicking a human expert's procedure. An idea for it is "fatness" which can be easily calculated by the following equation:

Condition factor (fatness)

$$= \frac{\text{weight of fish}}{(\text{essential length of fish})^3} \times 1000 \qquad (1)$$

3. Experimental Analysis of the Drying Process

The fish used for the material were caught off the coast of Yamaguchi Prefecture from September to October in 1991. The purpose is to produce half-dried fish. Drying conditions was as follows. 28 hours of drying is often employed by an expert. The same amount of time is also used here.

(Cool-air drying)

Conditions:

Drying temperature = 21.8 °C

Moisture (Relative humidity of the drying room at the beginning) = about 70 %

Wind flow rate = 3.11 m/s

Judgement of the status of finish after 24-hour- or 28-hour-drying, the products were evaluated and classified into 5 ranks, A to E. The interpretation of each rank is shown in Table 3.

Table 3 Interpretation of ranking of expert's evaluation

Rank	Expert's Judgement	Commercial value
A	Underdried	None
B	Slightly underdried	Good
C	Proper	
D	Slightly overdried	
E	Overdried	None

Table 4 Change in weight with elapsed drying time

Condition factor = 12.76

Class	Average length	Change in weight (%)						
		0h	4h	8h	12h	20h	24h	28h
160mm	161.2mm	100.0	88.0	83.2	79.3	73.4	70.8	68.9
170mm	170.0mm	100.0	89.7	85.5	82.3	77.3	74.9	73.0
180mm	179.5mm	100.0	90.6	86.9	84.0	79.3	77.1	75.4

For the material of fatness 12.76 and of length 160, 170 and 180mm, the changes in weight with elapsed drying time is shown in Table 4.

As is clear in Table 4, the larger the length is, the smaller the drying rate is, under the same drying temperature. This comes from the fact that fat hampers drying and that such fat especially right under the fish skin is relatively thick for a large fish because of the large body thickness, among the fish of the same fatness.

4.Discussion and Conclusion

One of important facts found by the present analysis is that the condition factor which is a measure of fatness plays a central role in dealing with fish drying.
Fig.2 shows an expert's judgement of the states of finish for the products after 24 hours of drying. Fig. 3 shows the results of mechanical testing for the specimens from the ranks A to D. These figures imply that an expert's judgement of the state of finish is made using his delicat sensory inspection like seeing, touching, and weighing fish in his hand.
The above analysis together with the modeling in Reference [7] will be used in constructing an intelligent control system for fish drying. The authors idea is shown in Fig. 4 schematically.

Acknowledgment

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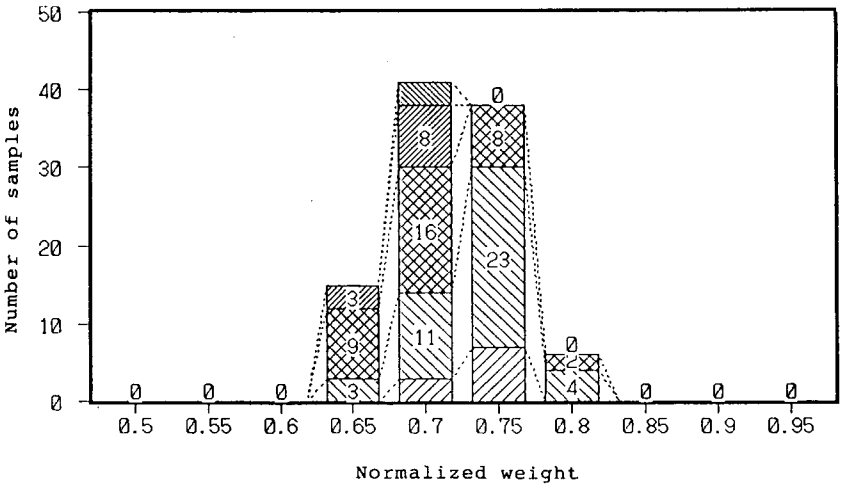

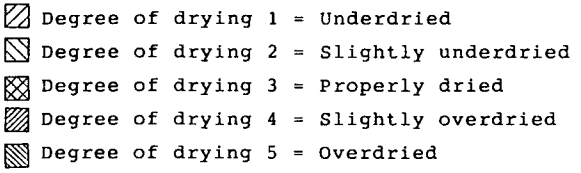

Fig. 2 Degree of drying versus normalized weight of 24h drying

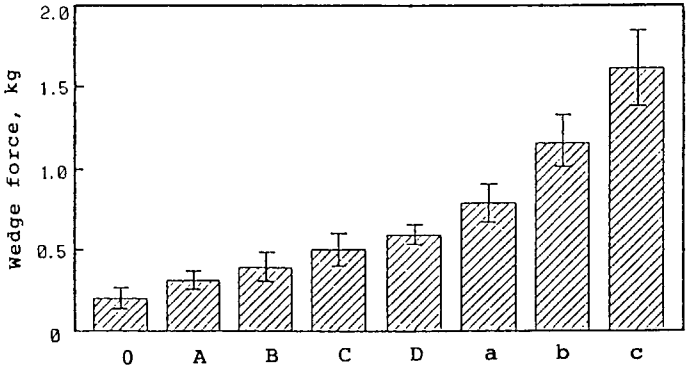

Fig. 3(a) Comparison of wedge force required in penetrating fish surface

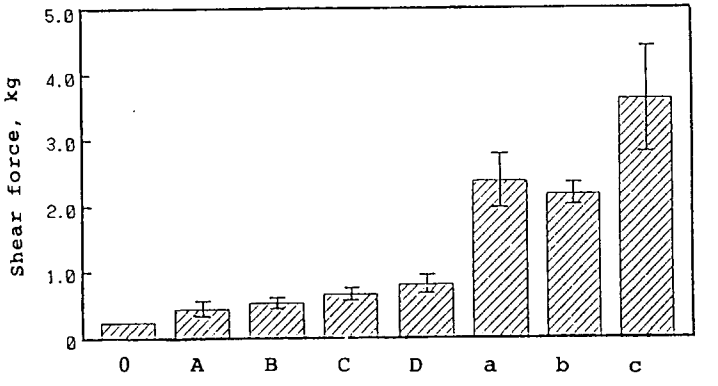

Fig. 3(b) Comparison of shear force in shearing fish meat

Symbol 0 = Raw fish
Symbols A to D corresponds to the ranking A to D indicated in Table 3.
Symbols a to c = Commercially available products

Fig. 3 Comparison of hardness among raw fish, products of rank A to D, and some commercially available products

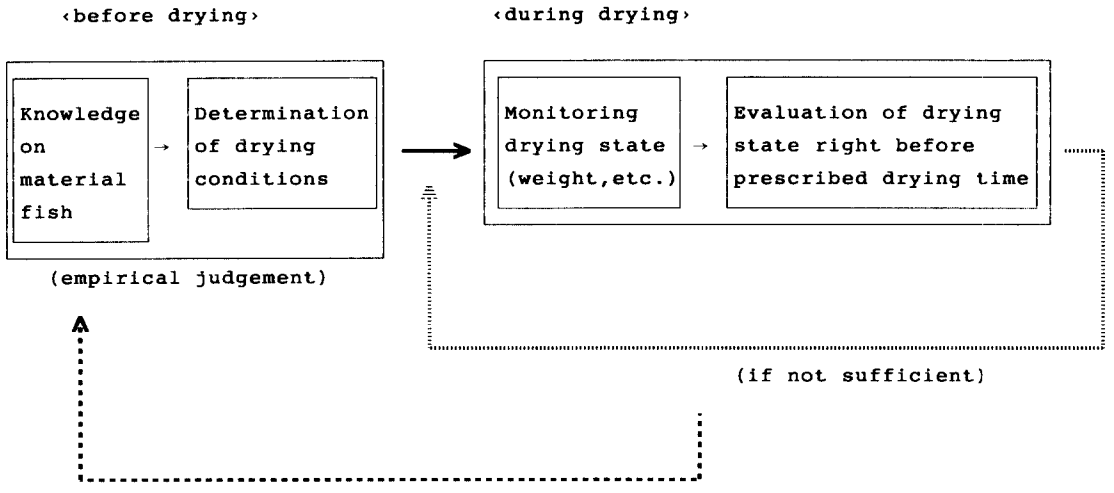

Fig. 4 Schematic of the authors' proposing control system for fish drying process

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