EXPERIMENTS ON FREEZE DRYING OF MEAT

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Investigations on the freeze drying of precooked meat were carried out to standardize conditions of drying, namely tray loading density and surface temperature and compare the contact and radiant methods of heat transfer. Freeze dried mutton of satisfactory quality was obtained by arranging cooked meat on trays at the rate of 9·76 kg/ m^2 and dehydrating it by contact heat at a surface temperature of 50°C. When the material is arranged in double layers, with an aluminium mesh insert in- between and a total loading density of 18·3 kg/m^2 tray surface, time for dehydration increases, but not proportionately with the loading density. The radiant method of heat transfer yields a better product, with reduction in dehydration time as compared to the contact method of heat transfer.

In an earlier paper[1] freeze drying of foods, employing the radiant and contact methods of heat transfer, was described and relative merits of the two methods discussed. This paper studies the effects of surface temperature and tray loading density on quality of dried product and the dehydration cycle. It also describes the effect of distance of the heating source from the food tray during freeze drying by the radiant method of heat transfer.

MATERIAL AND METHODS

Dressed meat (mutton), conforming to ASC specification, was obtained from the Army Supply Corps butchery. After removal of the superficial fat, the meat was deboned, cooked for 30 to 35 minutes in steam at a pressure of 1.05 kg/cm^2, frozen without gravy and finally sliced into 15-16 mm thick chunks. These were then spread uniformly on trays to the required loading density. In the 'contact method' of heating, steel trays were used with aluminium mesh inserts (expamets) above and below the material to facilitate conduction of heat and vapour flow. The upper expamet was covered by a steel cover. In the 'radiant method' of heating, the material was arranged in aluminium trays having raised edges and painted black on the outside and polished bright on the inside. The distance between the heat source and the surface of the food was maintained by inserting spacers made of insulating material.

Thermocouples were inserted deep inside the pieces which were then kept for deep freezing (—30°C). When the material was frozen the trays were removed to the food chamber of the freeze drying cabinet for dehydration. An extremely low uniform pressure of 0·1 mm of mercury was maintained in the food chamber throughout the drying process. In the 'contact method' of heat transfer, a pressure of 0·14 kg/cm^2 was maintained on the food surface during the complete drying cycle. Heat supply from electric plate heaters was regulated to maintain the desired surface temperature. The freeze dried product, immediately after removal from the drying cabinet, was nitrogen packed in sterilized sanitary double seamed tin containers. The dried products obtained under different sets of drying conditions were tested for their relative reconstitution/rehydration ability and also analysed for moisture, protein and fat by usual methods[2].

EXPERIMENTS AND RESULTS

Effect of food surface temperature on the drying cycle

The effect of food surface temperature of 45°C, 50°C and 60°C on the freeze drying cycle was studied at a loading density of 9·76 kg/m². At these temperatures, adequate dehydration of a batch was obtained in 11 hr. 10 min. 9 hr. 30 min. and 8 hr. respectively.

Effect of loading density on the drying cycle

Precooked mutton chunks arranged on trays were deep frozen and freeze dried keeping the food surface temperature at 50°C. The chunks were loaded at the rate of 8·54, 9·76, 10·98, 12·2 and 18·3 kg/m² of tray surface area. Difficulties were, however, experienced in loading at 10·98 and 12·2 kg/m². Although it is normally possible to achieve these loading densities in monolayers in case of raw meat, cooked meat posed difficulties because of its lower bulk density. Loading density of 18·3 kg/m² was achieved by arranging the material in two layers on the tray (lower layer 9·76 kg/m² and upper layer 8·54 kg/m² (with an expamet in-between). Data on drying cycles corresponding to different tray loading densities are given in Table 1.

Effect of distance between the heater plate surface and the food tray on the freeze drying cycle in the radiant method of heat transfer.

Precooked mutton chunks were arranged on the trays (Loading density 9·76 kg/m²), deep frozen and freeze dried, maintaining surface temperature of the pieces at 50°C. Complete dehydration took 7 hr. 20 min. and 10 hr. respectively when a distance of 3 mm and 6 mm. was maintained between the heaters and the trays.

Rehydration and chemical analysis of freeze dried mutton

Data on important chemical constituents of freeze dried meat under different sets of drying conditions are presented in Table 2. Data on rehydration ability of freeze dried meat are given in Table 3.

TABLE 1

EFFECT OF LOADING DENSITY ON FREEZE DRYING CYCLE OF MEAT

(Contact heat transfer)

(Food Surface Temperature 50°C)

Loading density	Drying time taken			
	After starting the vacuum.		After switching on the heaters.	
(kg/m²)	Hr.	Min.	Hr.	Min.
8·54	9	15	8	55
9·76	9	30	9	0
10·98	9	20	9	0
12·2	9	20	9	0
18·3	12	55	12	30

TABLE 2

MOISTURE, FAT AND PROTEIN CONTENT OF FREEZE DRIED MEAT

Drying Conditions		Chemical composition		
Loading density (kg/m²)	Surface Temp. (°C)	Moisture %	Protein %	Fat %
8·54	50	1·4	85·0	9·9
9·76	50	1·4	85·0	10·0
10·98	50	1·3	85·2	9·8
12·2	50	1·4	85·0	10·0
9·76	45	2·2	84·6	10·2
9·76	60	1·3	84·5	9·2
9·76 (Radiant 3 mm)	50	1·6	86·0	8·7
9·76 (Radiant 6 mm)	50	1·5	84·6	10·2
18·3	50	1·5	84·0	10·1

TABLE 3

REHYDRATION ABILITY OF FREEZE DRIED MEAI BY SOAKING IN WATER

Drying conditions		Reyhdration (%) after (Time in min.)					
Loading density. (kg/m²)	Surface temp. (°C)	5	10	15	30	60	120
Contact Heating							
8·54	50	81·30	87·30	87·30	87·30	87·30	87·30
9·76	50	72·32	77·70	79·76	87·20	87·20	87·20
10·98	50	72·20	78·10	81·10	88·60	93·00	93·00
12·2	50	69·30	76·80	78·28	85·71	87·21	88·73
9·76	45	71·00	77·90	79·42	80·94	85·40	85·40
9·76	60	66·23	72·20	75·16	78·10	81·10	81·10
18·3	50	73·95	78·43	82·88	90·32	93·31	93·91
Radiant Heating							
9·76 (Distance 3mm)	50	77·30	81·51	83·90	86·60	89·30	89·30
9·76 (Distance 6mm)	50	96·30	96·30	96·30	96·32	96·30	96·30

Per cent rehydration was calculated by the relation

$$\frac{M-(W-m)}{(W-m)\times 1\cdot 7}\times 100$$

where W=weight of freeze dried material

m=water content in the dry product

M=weight of the material after rehydration

$1\cdot 7$=Ratio of water to solid in the freshly cooked meat

DISCUSSION

Superiority of the freeze drying technique over the conventional method for food dehydration has now been well established. However, for successful adoption of this technique commercially, conditions of drying have to be carefully standardized.

Effect of surface temperature on freeze drying of meat

Freeze dehydration of mutton at the food surface temperature of 60°C, 50°C and 45°C was completed in 8 hr., 25 min., 9 hr. 30 min. and 11 hr. 10 min. respectively. Food surface temperature of 60°C was achieved by maintaining the heater temperature at 120°C. Although it helped to shorten the drying cycle substantially, the material was found toget partially scorched. This corroborates a similar finding already reported[3]. Food surface temperature of 45°C was achieved with the heaters at 80°C. The product obtained after dehydration in this case was of good appearance and reconstituted well but the drying cycle became too long to make the process economical. Freeze drying, when carried out with the food surface temperature at 50°C, gave a product almost as good as obtained at 45°C and at the same time much reduced the drying cycle (Fig. 1).

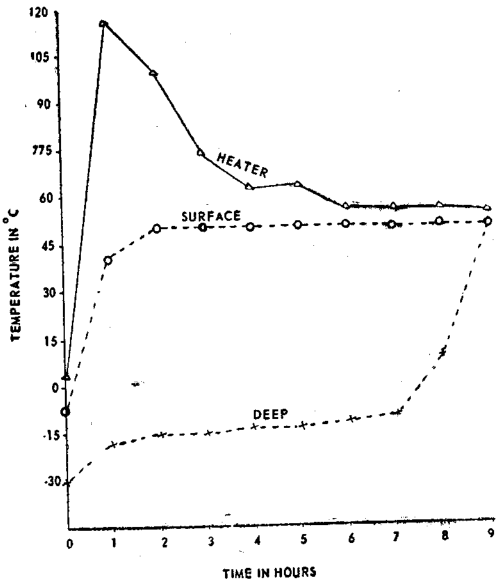

Fig. 1—Standard time temperature curve in the freeze drying of mutton chunks-loading density 9·76 gm/m² and food surface temperature 50°C (contact heat transfer)

Effect of distance between heater plate surface and the food tray on freeze drying cycle in the radiant method of heat transfer.

When distance between the radiating source and the receipient was 6 mm, the drying cycle (of 10 hr.) was longer than the corresponding cycle for contact method of heat transfer. However, with distance between the radiating source and the receipient reduced to 3 mm, the drying cycle became short and the dried product was better in appearance and reconstitution ability (Table 3) than the corresponding product obtained by the contact method of heat transfer.

Effect of loading density

It will be observed from Table 1 that the drying cycle with a food surface temperature of 50°C does not vary appreciably in the tray loading density range of 8·54 to 12·2 kg/m^2. However, when the loading density is 18·3 kg/m^2, the drying cycle is prolonged to 12 hr. 55 min. against 9 hr. 15 min. to 9 hr. 30 min. with tray loading desnities of 8·54 to 12·2 kg/m^2. This increase in the duration of the drying cycle is, however, compensated by more quantity of food thus freeze dried. This particular loading density deserves consideration in a commercial plant.

It has been reported[3] that raw lamb and cooked lamb slices when freeze dried at a loading density of 12·2 to 14·6 kg/m^2 require about 7½ hr. for complete dehydration, surface temperature and the thickness of the pieces being the same as in the present experiments. The difference may be attributed to the age of animals used for obtaining meat in the two cases, *i.e.*, 1½ to 2½ years in the present experiments and 6 months to 1 year in the case of other workers[3].

Chemical analysis and rehydration

There were no wide variations in the chemical composition of the freeze dried products obtained under different drying conditions-moisture varied from 1·4 to 2·2 per cent, protein from 84 to 86 per cent and fat content ranged from 8·7 to 10·2 per cent (Table 2). From Table 3, it will be observed that the material freeze dried with radiant heating gave a product which reconstituted better than the one obtained by contact heat transfer. In radiant heating, with distances of 3 and 6 mm. between the food and the heater plate surface, it rehydrates to 77·3 and 96·3 per cent respectively. Though rehydration ability (in 5 minutes) in the former case was somewhat less than in the later case, it compared favourably with that of the product freeze dried by the contact method of heat transfer. In case of the contact method of heat transfer, the product dried with its surface temperature at 50°C rehydrated better than the one at 60°C while there were no marked differences in the properties of the products dried with their surface temperature at 45° and 50°C.

CONCLUSION

A loading density of 9·76 kg/m^2 and food surface temperature of 50°C appear to be the best for freeze drying precooked meat (mutton) chunks of 15 to 16 mm thickness by both the methods.

The freeze drying cycle becomes longer at a loading density of 18·3 kg./m^2 but the product is not adversely affected. This loading density may be advantageous for production on a commercial scale.

In general radiant method of heat transfer, with a 3 mm spacer, yields a better quality of freeze dried product than contact heating.

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REFERENCES

1 CHOWDHARY, B.S., SHARMA, S.K., SHARMA, T.R. & RANGANATHAN, V., *Def. Sci. J.*, 15 (1965), 209.

2 JACOB MORRIS B., "The Chemical Analysis of Food and Food Products", (D.Van Nostrand Co., Inc., Princeton, New Jersey, N.Y.) 1962.

3 "The Accelerated Freeze Drying Method of Food Preservation", (HMSO, London) 1961.