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REDUCING SHRINKAGE IN CANNED AND FROZEN MUSHROOMS

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ABSTRACT

The process involving a preliminary soaking of the mushrooms in water for 20 min followed by a chill storage period followed by a further water soak for 2 hr, and known as the 3S process, gave a considerable reduction in total shrinkage in both brown and white strain canned mushrooms compared with the control samples. Water uptake by the mushrooms in the 3S process was greatest when the soaking water temperature was between 20 and 30°C and had a pH of 8.

Citric acid in the blanch water enhanced the colour of the canned 3S treated mushrooms. Blanching in water at pH 8 gave better weight retention in the canned 3S product than when pH values were lower and the addition of starch to the blanch water also reduced blanching loss. Prestoring mushrooms for 72 hr prior to the 3S process had no effect on total shrinkage values but gave a less white canned product.

The use of the 3S process on mushrooms for freezing resulted in better weight retention after blanching, but a less white product, compared with mushrooms that received a straight water soak, or no water soak.

INTRODUCTION

Shrinkage due to loss of solids and water is a major problem in the canning of mushrooms with losses in the order of 30-40% (1). In frozen mushrooms it occurs during blanching and is usually about 28-30%. Attempts have been made to reduce shrinkage in canned and/or frozen mushrooms using a range of procedures (2-7). The 3S process for reducing shrinkage was developed at Pennsylvania State University USA (8-10) and involves soaking the mushrooms in water for 20 min, followed by chill storage at 2-4°C (for periods of 24, 48 or 72 hr), followed by a further water soak (2 hr), i.e. soak, store, soak—hence the term 3S. The mushrooms are then blanched and canned conventionally. It is claimed (11) that the 3S process alters the nature of the protein fraction in the mushrooms and enables them to hold more water.

This study investigated the use of the 3S process for the reduction of shrinkage in canned and frozen mushrooms and also the interaction of the 3S process with various prestore, soaking, blanching and can 'top-up' procedures. The canning tests were carried out using a brown and a white strain from a number of different crops and the freezing study on a white strain. Degree of shrinkage was assessed at the various stages of the canning or freezing process (based on weight loss) and the mushrooms were assessed for colour, texture and flavour.

This study was included as a contribution to the EEC COST 91 Programme Sub-Group 3, dealing with the freezing and thawing (TTT-PPP) of foods.

MATERIALS AND METHODS

Brown and white strain mushrooms (*Agaricus bisporus*) were used; the brown strain was obtained from Kinsealy Research Centre and the white strain from a commercial grower.

The general procedures used were as follows with modifications being given under the various subheadings below: the samples (1.5-3 cm cap diameter) were tested on the day of picking, unless stated otherwise, with the stems being trimmed to 0.5 cm. The mushrooms (1.2 kg lots) for the 3S process were soaked in 6 l of water at 20°C for 20 min. After draining and weighing they were stored at 2-4°C in conventional mushroom chips covered with a polythene sheet for 24, 48 or 72 hr. They were then soaked in water again (6 l) at 20°C (initial water temperature) for 2 hr; after draining (2 min) and weighing they were blanched for 5 min in 1.5% citric acid solution, unless stated otherwise, cooled in running water (5 min) and weighed to assess blanching loss. After blanching 275 g lots were filled into plain cans (300 × 408¾), topped up with 1.5% brine at 90°C and retorted for 0.5 hr at 121°C. There were 3 cans for each replicate in all experiments. The canned mushrooms were then stored for at least 4 weeks before testing. Drained weight was assessed after draining for 2 min on a stainless steel mesh followed by weighing (2). Shrinkage during blanching and retorting was then calculated. Blanching loss was based on the weight of the fresh mushrooms prior to washing.

Having obtained a product with a reduced level of shrinkage it is important to evaluate it for colour, texture and flavour. Hence, the whiteness of 10 mushrooms from each can was tested with a Hunter Colour Difference meter (L values) using a 2.5 cm aperture; texture was measured on 100 g lots of the canned mushrooms using a shear press fitted with a standard test cell and results are given as kg. Flavour was assessed on sautéed mushrooms using paired comparison or rank type taste panels (12).

3S process in relation to crops and strains

Experiments (5 replicates) were carried out on three occasions (3 different crops, brown strain) comparing the different storage times (24, 48, 72 hr) of the 3S process for canned mushrooms. The samples were blanched in water. A non-3S sample (0 3S) was used as a control.

Further replicated 3S canning tests were carried out on a brown strain from 6 different crops and on a white strain from 4 crops (water blanched) to assess variation in canning performance between the two strains and from crop to crop. These tests were confined to the 72 hr storage treatment only, i.e. 72 hr 3S. Regression analyses of blanching loss × weight gain in 72 hr 3S mushrooms were carried out on the individual values from this part of the experiment.

Effect of soaking temperature in the 3S process

Mushrooms (white strain, 3 replicates) were soaked in water at temperatures of 2, 10, 20, 30 and 50°C during the 2 hr soak period of the 72 hr 3S process to study the

influence of soaking temperature on water uptake and subsequent shrinkage in the samples. These temperatures were maintained over the period by the removal/addition of warm water/ice and vice versa. The samples were blanched in 1.5% citric acid and were processed as outlined above.

Citric acid and mushroom colour, texture and flavour in the 3S process

Mushrooms canned without the use of citric acid in the blanch water usually have a dull colour and so it was decided to study the effect of citric acid in the blanch water on the shrinkage, colour, texture and flavour of 72 hr 3S canned mushrooms. Mushrooms (brown strain) from the 72 hr 3S process (5 replicates) were blanched in water containing 0 or 1.5% citric acid and were canned and evaluated as outlined above. The flavour of the samples was compared by a 20 member paired comparison taste panel.

Tests (unreplicated, white strain) were also carried out to see if a similar colour enhancing effect could be obtained for water blanched (no citric acid) 72 hr 3S mushrooms by topping-up the can with 1.5% brine containing 0, 0.2, 0.5, 0.8 and 1.0% citric acid. The samples were evaluated for flavour by a ranking procedure.

pH of soak/blanch water and the 3S process

Experiments were carried out to study if the pH of the soaking or blanching waters used for 72 hr 3S canned mushrooms had an effect on water uptake, shrinkage, colour and texture of the product.

Mushrooms (white strain) in the 72 hr 3S process were soaked in water (both 20 min and 2 hr soaks) of pH 2, 4, 6 or 8; there were no replicates. These pH levels were achieved using either phosphoric acid or sodium hydroxide. The final pH values of the water after the 2 hr soak were 2.05, 4.75, 6.10 and 8.30 respectively. The samples were then blanched in 1.5% citric acid solution and were canned and evaluated as outlined above.

Mushrooms (white strain) from the 72 hr 3S process were blanched in water (no citric acid) of pH 2, 4, 6 or 8; there were 3 replicates. These pH values were achieved using phosphoric acid or sodium hydroxide and the samples were canned and evaluated as outlined above.

Effect of starch in the 3S process on mushroom shrinkage

Most of the mushroom solids lost during blanching and retorting are carbohydrates and so it was decided to add starch to the blanch water, or to the can top-up liquor, to see if it would retard the loss of solids and so reduce shrinkage in the blanched and canned product.

Mushrooms (white strain) from the 72 hr 3S process were blanched in water containing 0, 1, 2 and 4% "Snowflake" starch. No citric acid was used and there were 3 replicates. The samples were canned and evaluated as outlined above. In the can 'top-up' test, "Snowflake" starch was added to the 1.5% brine top-up liquor at the rate of 0, 1, 2 or 4%.

Effect of prestoring mushrooms on the 3S process

In commercial practice, mushrooms are often held in chill prior to processing, especially over weekends. Tests were carried out to study if this practice influenced the 3S process as follows: samples of mushrooms (white strain, 5 replicates) were stored for 72 hr at 4-5°C, in chips, in a refrigerator prior to 72 hr 3S treatment. Control samples were subjected to the 72 hr 3S treatment without any prestore period. All samples were blanched, canned and evaluated as outlined above; blanching was carried out in 1.5% citric acid solution.

Mushroom freezing and the 3S process

A comparison was made of 'wash only' vs 3 hr straight water soak vs 72 hr 3S process on shrinkage, colour and texture of frozen mushrooms.

Samples (1.2 kg lots, white strain, 4 replicates) received one of three preblanching treatments, i.e. wash only vs soak for 3 hr in water at 20°C vs 72 hr 3S process. The samples were blanched in water for 5 min and were blast frozen in polythene bags for 2 hr at −24°C and thawed for 5 hr at 15-20°C after which they were evaluated for weight loss, colour and texture.

RESULTS AND DISCUSSION

3S process in relation to crops and strains

The results for one of the crops tested are given in Table 1; similar data were obtained for the other two crops.

As expected, a considerable amount of water was taken up during the 3S process and this resulted in a much lower blanching loss for the 3S samples with the smallest losses for the 72 hr samples (Table 1). Total shrinkage ex-can was lowest at 23.9% for the 72 hr 3S process compared with a value of 39.2% for the control; values for the 24 and 48 hr 3S samples were also considerably better than the control (Table 1). These data show that the 3S treatment greatly improves weight retention in canned mushrooms and these findings agree with those of other workers (8-10).

The data (Table 1) show that the 3S process adversely affected the colour of the canned product with a Hunter L value of 53 for the control compared with a value of 46 for the 72 hr 3S sample. These samples were blanched in boiling water; however, blanching in citric acid solution overcomes this problem (see Table 5). The 3S process also gave canned mushrooms with a higher shear reading; however, all samples were acceptable from a texture point of view. There was also a greater tendency for veils to break in the 3S treated samples but the effect was not statistically significant.

The 3S treated samples were less preferred for flavour by a taste panel than the control sample (Table 1). However, it must be stressed that the 3S treated samples were not off-flavoured and were perfectly acceptable to the taste panel.

TABLE 1: Shrinkage, colour, texture and flavour of canned mushrooms[1] from the 3S process (i.e. 0, 24, 48 or 72 hr storage)

	3S process (hr)					
	0	24	48	72	F-test	SE
Water uptake (%)	9.4	26.0	28.6	29.3	$p<0.001$	0.6
Blanch loss (%)[2]	27.9	19.9	11.6	8.7	$p<0.001$	0.6
Retort loss (%)	15.7	13.5	16.0	16.7	$p<0.001$	0.6
Total shrinkage (%)[3]	39.2	30.7	25.8	23.9	$p<0.001$	0.6
Texture (kg)[4]	79	83	82	90	$p<0.01$	2.3
Colour (Hunter L)	53	60	50	46	$p<0.001$	1.8
Open veils (%)	0.7	0.1	3.3	3.0	NS	1.0
Flavour[5]	28 (1st)	41 (3.5)	41 (3.5)	40 (2nd)	NS	—

[1]Brown strain
[2]Based on fresh mushroom weight
[3]Based on difference between fresh weight and drained weight
[4]Shear press, 100 g sample
[5]Rank-type taste panel; 4 samples × 15 tasters; range for significance = 28-47 ($p<0.05$)

TABLE 2: Water uptake, blanching loss, retort loss and total shrinkage in brown and white strain 72 hr 3S canned mushrooms from different crops

	Water uptake %	Blanch loss[1] %	Retort loss %	Total shrinkage %
Brown strain				
Crop 1	30.1	8.6	19.6	26.5
2	29.3	8.7	16.7	23.9
3	24.6	15.4	14.3	27.1
4	28.6	11.4	14.8	24.7
5	25.3	11.2	16.2	25.6
6	28.7	10.6	16.1	25.5
Mean (n = 48)	27.8	11.0	16.3	25.6
White strain				
Crop 1	31.2	12.0	11.0	21.7
2	30.7	7.5	13.6	20.0
3	29.4	9.7	14.4	22.8
4	33.3	13.7	10.5	22.8
Mean (n = 16)	31.2	10.7	12.4	21.8

[1]Based on fresh mushroom weight

The results (Table 2) show that total shrinkage was lower for the white strain (21.8%) than for the brown strain (25.6%). Blanch losses were similar for the two strains but the brown strain had a higher (16.3%) retort loss and a lower water uptake (27.8%) value than the white strain (12.4% and 31.2% respectively). Variation in performance from crop to crop was fairly similar with respect to water

uptake, and total shrinkage (Table 2). However, mushrooms from crops 1 and 2 of the brown strain and from crop 2 of the white strain had much lower blanching losses than samples from the other crops (Table 2).

The results show, therefore, that the white strain performed slightly better in the 3S process than the brown strain. The main differences between crops were in the blanching losses, retort loss and total shrinkage.

Regression analyses

There was a significant inverse ($p<0.001$) relationship between weight gain (i.e. water soaked-up) and blanching loss for the brown strain (Table 3) but not for the white strain. This was due to the fact that some samples of the white strain had exceptionally low blanch loss values and also a much narrower range of water uptake values (% CV = 7.8) compared to the brown strain (%CV = 11.5).

In the case of retort loss × blanch loss there was no relationship in the brown strain mushrooms but there was an inverse relationship ($p<0.05$) for the white strain (Table 3) indicating that if shrinkage was low during blanching tehn it would be higher during retorting and vice versa.

TABLE 3: Relationship between water uptake and blanching loss, and blanching loss and retort loss in brown and white strain mushrooms[1]

Dependent variable	Independent variable	Strain	Equation of line	Correlation coefficient	t-test
Blanch loss (%)	Water uptake (%)	Brown	y = 22.17-0.39x	—0.46	p<0.001
		White	y = 11.35-0.02x	—0.04	NS
Retort loss (%)	Blanch loss (%)	Brown	y = 15.95-0.003x	—0.01	NS
		White	y = 17.13-0.47x	—0.50	p<0.05

[1]Footnotes as in Table 1

The inconsistency of the trends in the data above for the brown and white strains indicate again that the water uptake-blanch loss inter-relationship is not straightforward and can vary from one batch of mushrooms to another. However, in general, it seems that a high water uptake by mushrooms tends to give a lower blanch loss value.

Effect of soaking temperature in the 3S process

Water uptake at the five temperatures was significantly different, ranging from 23.5% at 2°C to 35.1% at 30°C (Table 4). This was reflected in the blanching losses with corresponding values of 13.3 and 8.7%; however, these values were not significantly different due to the large standard error term (Table 4). The corresponding retort losses were 13.0 and 12.7% and total shrinkage values of 24.6 vs 20.3% (Table 4). There was no difference in the texture of the canned samples but

TABLE 4: Effect of the temperature of the soaking water on water uptake, shrinkage, colour and texture of canned mushrooms (white strain) from the 72 hr 3S process[1]

	Temperature of soak water (°C)						
	2	10	20	30	50	F-test	SE
Water uptake (%)	23.5	27.6	33.9	35.1	26.3	$p<0.01$	1.5
Blanch loss (%)	13.3	11.1	9.4	8.7	12.4	NS	3.0
Retort loss (%)	13.0	13.2	12.2	12.7	12.5	NS	1.3
Total shrinkage (%)	24.6	22.8	20.5	20.3	23.4	NS	1.6
Texture (kg)	96	92	94	93	100	NS	5.4
Colour (Hunter L)	57	57	58	57	45	$p<0.01$	2.2
Open veils (%)	3.9	8.1	6.0	7.1	4.3	NS	4.5

[1]Footnotes as in Table 1

mushrooms soaked in water at 50°C had an inferior colour ($p<0.01$) to the other canned samples despite being blanched in citric acid (Table 4). Presumably enzyme activity was too high in these mushrooms during the 2 hr soak period and browning took place. There was no significant difference between treatments for the percentage of open veils; however, the overall level of open veils was too high. These data suggest that the ideal water soaking temperature for mushrooms in the 3S process is between 20-30°C.

In practice all other samples in these experiments were soaked, for convenience, in water with an initial temperature of 20°C. The mushrooms (1.2 kg) for the 2 hr soaking (6 l water) were coming from the chill (2-4°C) phase of the 3S process and so the water was cooled to 16°C shortly after addition of the samples; this value had risen to 16.5°C after 1 hr and 17°C after 2 hr. These soaking temperatures are close to those of 10-16°C reported by other workers (7).

Citric acid and mushroom colour, texture and flavour in the 3S process

The results (Table 5) indicate that citric acid in the blanch water improved ($p<0.001$) the whiteness of the canned product (Hunter L = 50 control, and 58) without influencing the weight enhancing effect of the 3S process in terms of water uptake, blanching loss, retort loss and total shrinkage. However, there were more

TABLE 5: Effect of citric acid in the blanch water on shrinkage and colour of canned mushrooms (brown strain) from the 72 hr 3S process[1]

	Citric acid (%) in blanch water			
	0	1.5	F-test	SE
Water uptake (%)	28.9	28.3	NS	2.3
Blanch loss (%)	10.9	11.9	NS	2.2
Retort loss (%)	15.6	14.7	NS	1.0
Total shrinkage (%)	24.8	24.8	NS	2.7
Colour (Hunter L)	50	58	$p<0.001$	0.8
Open veils (%)	5.8	14.1	NS	5.9

[1]Footnotes as in Table 1

mushrooms with open veils from the citric acid treatment. The pH of the 1.5% citric acid solution used for blanching was 2.3.

Topping up the cans of water blanched mushrooms with brine containing 0, 0.2, 0.5, 0.8 and 1.0% citric acid also had an enhancing effect on canned mushroom colour. Corresponding Hunter L values were 53, 59, 62, 61 and 64 respectively, indicating a large colour enhancing effect between 0 and 0.2% citric acid; however, higher levels had only a small additional effect. In addition, the taste panel was able to detect the increasing levels of citric acid. This suggests that 0.2% citric acid is the maximum level that would be tolerated from a flavour point of view. The addition of citric acid to the top-up liquor adversely affected retort loss which ranged from 12.3% for the 0 citric acid treatment to 14.4% for the highest citric acid level.

pH of soak/blanch water and the 3S process

Soaking mushrooms at different pH values in the 72 hr 3S process had no marked influence on water uptake with values ranging from 29.3% at pH 2 to 32.9% at pH 8; however, a large difference became apparent after blanching with a loss of 15.2% for samples soaked at pH 2 grading down to only 8.9% for those soaked at pH 8. This effect was carried over after canning to give a total shrinkage of 26.0% and 21.3% respectively. The soaking treatments did not influence mushroom colour but the samples soaked at pH 6 had a much firmer texture (109 kg) than the other samples (97-101 kg). These results suggest that soaking mushrooms in water in the 72 hr 3S process should be carried out at a pH of 6-8. This took place in practice in all of the tests as the tap water at Kinsealy Research Centre has a pH of 7.2.

The results (Table 6) indicate that blanching at high pH gives a smaller blanch loss and total shrinkage than blanching at low pH. This result contrasts directly with that found when blanching was carried out in 1.5% citric acid solution (pH 2.3); the citric acid blanch treatment was no different from the water blanch (pH 7.2) in terms of blanching loss or total shrinkage in the canned product (Table 5). This suggests that the effect on blanching loss and total shrinkage may be due to the phosphoric acid or sodium hydroxide used for pH adjustment and not to the pH itself.

TABLE 6: Effect of pH of the blanch water in the 72 hr 3S process on shrinkage, colour and texture of the canned product[1]

	pH of blanching water					
	2	4	6	8	F-test	SE
Water uptake (%)	31.3	32.3	30.9	31.3	NS	1.8
Blanch loss (%)	12.0	8.9	9.0	6.6	NS	2.3
Retort loss (%)	11.0	12.2	11.7	12.0	NS	1.6
Total shrinkage (%)	21.7	20.0	19.7	17.8	$p<0.05$	1.0
Colour (Hunter L)	50	48	51	53	$p<0.05$	1.2
Texture (kg)	97	94	94	97	NS	5.0
Open veils (%)	4.4	2.7	3.5	3.0	NS	1.2

[1]Footnotes as in Table 1

Effect of starch on mushroom shrinkage in the 3S process

The results (Table 7) show that blanching loss ranged from 7.5% for the water blanch treatment to 1.9% for the 4% starch treatment; this indicated that starch had a positive effect in reducing blanching losses. However, the 4% solution was viscous and tended to 'coat' the walls of the blancher. The low blanching losses from the starch treatments were carried over during retorting with the 2% starch blanching treatment giving a total shrinkage value of only 14.6% (Table 7). This represents a considerable reduction in shrinkage when compared with the value of 20.1% for the control treatment. The starch blanch treatment had no affect on the colour or texture of the canned product; neither did it influence the percentage of open veils although the value for open veils for all treatments was too high.

Inspection of the statistical data in Table 7 show that there were no statistically significant differences between the treatments despite the fact that there were large numerical differences between the values, especially in the case of blanching loss, retort loss and total shrinkage. This was caused by high values for within-treatment variance (Table 8). This in itself is an important result as it suggests that similar effects would probably face the large-scale processor who at any one time is canning mushrooms from many crops and growing sources. The statistical F-test is based on fairly similar values for within-treatment variance and hence does not apply here rigorously in most cases. However, despite the lack of statistically significant differences, important trends can be seen from the results.

Starch in the can top-up liquor had no effect on retort loss with values ranging from 11.2% for the control to 11.7% for the 4% starch treatment.

TABLE 7: Effect of starch in the blanch water on shrinkage, colour and texture in 72 hr 3S canned mushrooms[1]

	Starch (%) in blanch water					
	0	1	2	4	F-test	SE
Water uptake (%)	30.6	30.8	32.2	31.9	NS	2.8
Blanch loss (%)	7.5	4.3	2.2	1.9	NS	2.9
Retort loss (%)	13.6	14.8	12.7	14.4	NS	1.6
Total shrinkage (%)	20.1	18.6	14.6	16.1	NS	2.0
Colour (Hunter L)	50	51	51	49	NS	1.9
Texture (kg)	94	86	90	85	NS	5.9
Open veils (%)	15.9	17.9	19.3	18.1	NS	15.3

[1]Footnotes as in Table 1

TABLE 8: Values for within-treatment variance for some of the factors in Table 7

	Starch (%) in blanch water			
	0	1	2	4
Blanch loss (%)	4.60	15.82	18.36	12.58
Retort loss (%)	1.24	7.00	1.14	5.97
Total shrinkage (%)	1.21	0.75	18.60	3.48

Effect of prestoring mushrooms on the 3S process

The results (Table 9) show that the prestored samples lost 7.3% in weight during storage in the fridge for 72 hr. This loss was not recovered during the 2 hr water soak of the 72 hr 3S process, as water uptake was 15.8% based on the mushroom weight before prestore; the corresponding uptake for the control sample (72 hr 3S) was 29.3%. The difference in water uptake resulted in a blanching loss of 9.7% for the control sample compared with 13.3% (based on weight prestore) ($p<0.05$) for the prestore sample (Table 9). However, the prestore sample had a lower ($p<0.01$) retort loss at 12.3% than the control sample (14.5%). This offset the difference in blanching loss for the two treatments and resulted in the total shrinkage values being similar at 23.9 and 22.8% respectively (Table 9). The colour of the prestore sample was inferior ($p<0.001$) to that of the control sample while the texture was firmer ($p<0.001$).

TABLE 9: Effect of a prestore[1] period on the subsequent performance of mushrooms in the 72 hr 3S process and on the quality of the canned product

	Prestore	No prestore	F-test	SE
Weight loss (%)[2]	7.3	—	—	—
Water uptake (%)[3]	15.8	29.3	$p<0.001$	0.8
Blanch loss (%)[3]	13.3	9.7	$p<0.05$	1.4
Retort loss (%)	12.3	14.5	$p<0.01$	0.5
Total shrinkage (%)	23.9	22.8	NS	1.2
Colour (Hunter L)	50	59	$p<0.001$	1.0
Texture (kg)	103	97	$p<0.001$	0.9
Open veils (%)	3.8	5.6	NS	1.0

[1]72 hr at 4-5°C
[2]During prestore
[3]Based on fresh weight, i.e. before prestore

These data show that prestoring mushrooms prior to the 72 hr 3S process had little influence on canned yield but had an adverse effect on the colour of the canned product.

Mushroom freezing and the 3S process

The 72 hr 3S treated mushrooms took up more water (30.1% gain in weight) than mushrooms soaked for 3 hr in water (25%) and had a blanch loss of only 12.2% (calculated on fresh weight prior to soaking) compared with 24.9% for the 3 hr soaked samples and 28.8% for the 'wash only' sample (Table 10). Weight loss on freezing (ca 2%) was similar for the three treatments but drip loss on thawing was highest in the 72 hr 3S treatment. Total weight loss (fresh to thawed) was 28% for the 72 hr 3S mushrooms, 38% for the 3 hr soaked sample and 40% for the 'wash only' sample. However, the favourable weight retention for the 72 hr 3S treatment mushrooms was offset by an inferior colour in the frozen product and by a tougher

Table 10: Effect of pre-blanch water soaking treatments on shrinkage, colour and texture of frozen mushrooms

	Treatment				
	Wash only	Water soak 3 hr	72 hr 3S process	F-test	SE
Weight gain (%)	—	25.2	30.1	$p<0.001$	0.3
Blanch loss (%)	28.8	24.9	12.2	$p<0.001$	0.3
Loss on freezing (%)	2.2	2.8	2.3	NS	0.3
Loss on thawing (%)	14.1	14.9	16.5	$p<0.01$	0.4
Total shrinkage (%)[1]	40.2	37.8	28.2	$p<0.001$	0.3
Colour (Hunter L)	63	65	62	NS	1.7
Texture (kg)	152	148	163	$p<0.05$	4.9

[1]From fresh weight to weight after thawing

texture in the thawed product (Table 10). The inferior colour of the 72 hr 3S samples was not truly reflected in the Hunter L whiteness readings.

These data show that the 72 hr 3S process has application for frozen mushrooms but further tests will need to be done to improve the colour of the frozen product. The data also show clearly the effect of the 72 hr 3S process in reducing blanching loss compared with samples that received a straight water soak, or just a water wash (Table 10).

CONCLUSIONS

The data from these tests show that the 3S process in combination with other treatments, such as starch blanching, is very effective in reducing shrinkage in canned and frozen mushrooms. However, the colour of the frozen product needs to be improved. There was also a wide range in the performance of mushrooms from different crops and strains in relation to the 72 hr 3S process and also to blanching and retorting. This could present difficulties for the processor who at any one time is canning mushrooms from many crops and growing sources.

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REFERENCES

1. McArdle, F. J. and Curwen, D. 1962. Some factors influencing shrinkage of mushrooms during processing. *Mushr. Sci.*, 5: 547.
2. Gormley, T. R. and MacCanna, C. 1980. Canning tests on mushroom strains. *Ir. J. Fd Sci. Technol.*, 4: 57.
3. Gormley, T. R. and Walshe, P. E. 1974. Frozen French fried mushrooms. *Proc. IVth Int. Cong. Fd Sci. Technol.*, Madrid, 4: 147.
4. Gormley, T. R. and Egan, S. E. 1975. Hot air blanching of mushrooms. *Proc. Vth Ann. Res. Conf. Fd Sci. and Technol.*, University College Cork, 34.
5. Gormley, T. R. and O'Sullivan, L. 1977. Water uptake by mushrooms. *Proc. 7th Ann. Res. Conf. Fd Sci. Technol.*, University College Cork, 17.
6. Gormley, T. R. 1972. Quality evaluation of frozen mushrooms. *Mushr. Sci.*, 8: 209.
7. McArdle, F. J., Kuhn, G. D. and Beelman, R. B. 1974. Influence of vacuum soaking on yield and quality of canned mushrooms. *J. Fd Sci.*, 39: 1026.
8. Beelman, R. B., Kuhn, G. D. and McArdle, F. J. 1973. Influence of post-harvest storage and soaking treatments on the yield and quality of canned mushrooms. *J. Fd Sci.*, 38: 951.
9. Parrish, G. K., Beelman, R. B., McArdle, F. J. and Kuhn, G. D. 1974. Influence of post-harvest storage and canning on the solids and mannitol content of the cultivated mushroom and their relationship to canned product yield. *J. Fd Sci.*, 38: 1029.
10. Beelman, R. B. and McArdle, F. J. 1975. Influence of post-harvest storage temperature and soaking on yield and quality in canned mushrooms. *J. Fd Sci., 40*: 669.
11. Eby, D. L., McArdle, F. J. and Beelman, R. B. 1977. Postharvest storage of the cultivated mushroom and its influence on qualitative protein changes related to canned product yield. *J. Fd Sci.*, 42: 22.
12. Gormley, T. R., and Sherington, J. 1978. Assessment of taste panellists. *Ir. J. Fd Sci. Technol.*, 2: 59.

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