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Shrinkage in canned mushrooms treated with xanthan gum as a pre-blanch soak treatment

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Summary

Vacuum treating freshly harvested mushrooms with a 1% xanthan gum solution (XVT) containing 0.25% sodium metabisulphite (SMBS) prior to blanching and canning gave a lower shrinkage value than for corresponding samples vacuum treated with water, or those canned by conventional means or the 3S process. A combination of chill storage (2–4°C) for 1–3 days coupled with 1% XVT was found best and gave even lower total canning losses (chill storage loss+blanch loss+retort loss); these were 6% lower than in he 3S process and 11.5% lower than for mushrooms canned by the conventional procedure. These data suggest that xanthan gum has considerable potential for reducing shrinkage in canned mushrooms. The XVT canned samples had an excellent colour and an acceptable texture. Further storage tests over a 9 month period with xanthan treated canned mushrooms showed than an SMBS level of 0.1% in the pre-blanch soak solution maintained an excellent colour in the canned product. No in-can mushroom shrinkage took place during the 9 month storage test.

Introduction

Shrinkage during processing is a major problem for the mushroom canner and has been the subject of considerable research in a number of countries (Beelman, Kuhn & McArdle, 1973; Gormley & MacCanna, 1980; Singh *et al.* 1982). Studies on the effects of different strains (Gormley & MacCanna, 1980) and the use of the 3S and a modified 3S process (Gormley & Walshe, 1982) on reducing shrinkage in canned mushrooms have been carried out in this laboratory recently. It was found that the 3S process in combination with other treatments was very effective in reducing shrinkage in canned mushrooms although there were some colour (slight browning) and texture (slightly too tough) problems. In tests at Kinsealy Research Centre in 1983 the incorporation of xanthan gum into mushrooms using a vacuum soak prior to blanching greatly reduced blanching losses in mushrooms for freezing (Gormley, 1984). This in turn led to the present study which investigated shrinkage in canned mushrooms treated with xanthan gum as a pre-blanch soak treatment.

Xanthan gum is a microbial polysaccharide produced in sugar fermentation medium by the bacteria *Xanthomonas campestris*. It is a heteropolysaccharide composed of the monomer units mannose, glucose and glucuronic acid and has a molecular weight of several millions. It is a permitted food additive in Ireland.

In the study described below there were three distinct experiments. Experiment 1 involved comparing the effect of xanthan gum (0.5 or 1.0%) applied as a pre-blanch soak treatment on mushroom blanch and retort losses; the data were compared with those for mushrooms canned by the standard procedure and also by the 3S process. The

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effect of length of chill storage between harvesting and canning on the performance of xanthan gum in reducing shrinkage was assessed in experiment 2. Experiment 3 was a long term trial and assessed the effects of different levels of sodium metabisulphite (SO_2) on canned mushroom colour and texture and also on changes in drained weight in canned xanthan gum treated mushrooms over a 9 month period.

Materials and methods

White strain (*Agaricus bisporus*) commercially grown mushrooms were used for all tests. The xanthan gum (Keltrol, Kelco/AIL International) and sodium metabisulphite (SMBS) were applied to the mushrooms as a solution. Mushrooms in the solution were subjected to a vacuum of 75 kPa for 0.5 hr. The samples were then washed, weighed, blanched (5 min in boiling water with 1.5% citric acid), cooled in water for 5 min and canned in 1.5% brine in plain cans (300×408) with lacquered ends at 121°C for 0.5 hr. The samples were assessed 2–3 weeks after canning, for drained weight (after 4 min), whiteness (Hunter L on five mushrooms—2.5 cm aperture) and shear press value (standard test cell, 100 g of whole mushrooms). Departures from this procedure (where they occur) are given below. Samples were compared with those (the control) canned by the standard procedure, which was the same as that above except that no pre-blanch soak treatment was given, and also with those prepared using the 3S process (Gormley & Walshe, 1982).

Experiment 1: Xanthan gum versus *3S treatment* versus *control*

The effect of xanthan gum (0.5 or 1.0% solution), applied as a pre-blanch vacuum soak treatment, on mushroom blanching and retort losses was compared with data for mushrooms canned by the standard procedure (control) and by the 72 hr 3S process (Gormley & Walshe, 1982). Batches of mushrooms (1.2 kg) each were vacuum treated with water, 0.5% xanthan gum or 1% xanthan gum solution on day 0 (day of harvesting) as described above. Each treatment also contained 0.25% SMBS. These treatments were compared with a control (water wash only—no vacuum treatment) and with mushrooms treated by the 72 hr 3S process; the soak solution for the 3S process also contained 0.25% SMBS. There were three replicates for each treatment and the canned mushrooms were evaluated as outlined above.

Experiment 2: Effect of chill storage/xanthan treatment

Experiment 1 was conducted using day 0 (harvested and processed the same day) mushrooms. However, in commercial practice mushrooms tend to be older post-harvest when processed. In experiment 2 batches of mushrooms were held for 0, 1, 2 and 3 days at 2–4°C prior to canning in order to study the effects of such a delay on overall weight loss and on canned product colour and texture. The term overall weight loss comprises weight loss during chill storage coupled with blanching and retort losses. In addition to the four time treatments there were three processing treatments, i.e., vacuum soak in water (WVT), vacuum soak in 1% xanthan gum solution (XVT), and the 72 hr 3S treatment. The level of SMBS in all water/solution soak treatments was 0.25% and blanching and retorting conditions were as outlined above. There were two replicates for each treatment, giving a 4×3×2 situation or 24 portions; lot size prior to storage and processing was 1.2 kg.

Experiment 3: Long term colour and shrinkage test

This test commenced in May 1984 and concluded in February 1985. It was felt that the SMBS level of 0.25% used in the soak water/solutions in experiment 1 and 2 was rather high and so it was decided to look at the effect on canned mushroom colour of using levels of 0, 0.05, 0.10 and 0.25% in the 1% xanthan gum solution. This experiment also afforded the opportunity of studying any further changes in mushroom shrinkage in-can over an extended period. The test involved the use of day 1 (i.e., chill stored for 24 hr at 2–4°C) mushrooms and the experimental design was four SMBS levels, four testing dates and three replicates. The canned samples were evaluated on 18 May, 7 July and 30 November in 1984 and finally on 15 February 1985 for drained weight, colour and shear value as outlined above. The samples were also tested for SO_2 content and pH value; 200 g portions were pureed and were placed in a Monier Williams apparatus for SO_2 analysis (Pearon, 1962). pH was measured on the liquor drained from the mushrooms in each can. It became apparent during the storage period that the higher levels of SMBS were causing some de-tinning. This was quantified in physical terms on the November and February tests dates by inverting the drained cans over the 5 cm aperture of the Hunter meter and measuring reflectance (L) values.

Results

Experiment 1: Xanthan gum versus *3S treatment* versus *control*

Vacuum soaking gave a larger water/solution uptake than the soak treatments of the 3S process (Table 1). The 1% XVT gave the smallest ($P < 0.001$) blanch loss followed by the 3S process and the 0.5% XVT. The effect of xanthan gum in conserving the loss of water and solids is shown clearly by comparing the WVT with the XVT (Table 1). There were no statistically significant differences between the percent retort loss values (Table 1); however, the 1% XVT and the 3S treatment had similar but significantly lower total loss (blanch+retort) values than the other treatments. The XVT mushrooms were also whiter and had a less tough texture than the 3S or control samples.

Table 1. Shrinkage, colour and shear press values for day 0 mushrooms canned using xanthan gum treatments in comparison with the 3S process and water treated controls

	Pre-blanching treatment*						
Factor/test	Control	72 hr 3S process	Vac. soak water	Vac. soak 0.5% xanthan gum	Vac. soak 1% xanthan gum	*F*-test	s.e.
Weight gain (%)	0	30.1	48.6	52.6	45.2	$P < 0.001$	1.08
Blanch loss (%)†	25.9	10.4	22.8	14.3	8.2	$P < 0.001$	0.34
Retort loss (%)	12.5	12.0	12.2	12.7	13.2	NS	0.54
Total loss (%)‡	35.2	21.2	32.2	25.3	20.3	$P < 0.001$	0.32
Whiteness (L)	54	67	73	72	70	$P < 0.001$	0.44
Shear press value (kN)	0.81	0.80	0.76	0.68	0.65	$P < 0.001$	0.01

*See materials and methods section.

†Based on fresh weight.

‡Comprises weight loss during blanching and retorting.

Experiment 2: Effect of chill storage/xanthan treatment

The weight losses in the chill storage (2–4°C) of mushrooms in 1.36 kg chips covered with polythene were 0, 2.3, 3.3, and 4.3% on days 0, 1, 2 and 3 respectively. This result was statistically significant ($p < 0.001$; s.e. = 0.09).

The data (Table 2) for the uptake of water/solution during the soak treatments show that there was a highly significant ($P < 0.001$) interaction between days of chill storage and the subsequent soak treatments. There was a progressive increase in water percent/solution taken up by the mushrooms following chill storage from 0 to 3 days for the WVT and the XVT samples while there was a decline in the amount of water soaked up in the 3S process with increasing chill storage time post-harvest. Chill storing mushrooms for up to 3 days prior to vacuum soaking is, therefore, advantageous in terms of the weight gained by the mushrooms during vacuum soaking in water or xanthan gum solution.

Blanching loss decreased (Table 2) with increasing time of chill storage of the mushrooms prior to blanching. The effect was most dramatic for the 1% XVT where a net gain in weight after blanching was recorded for mushrooms chill stored for 2 or 3 days prior to blanching; the blanching loss/gain was based on the mushroom weight post-chill storage and not on the inflated weight after vacuum soaking. Retort loss was

Table 2. Weight gain/loss for mushrooms held for 0–3 days in chill storage (2–4°C) prior to canning

Factor	Days stored in chill prior to processing*	Soak treatment*			
		Vac. soak water	Vac. soak 1% xanthan	3S soak	Mean
Water/solution uptake (%) during soaking	0	46.5	48.0	33.5	42.6
	1	49.0	53.5	29.0	43.8
	2	51.0	56.0	25.5	44.2
	3	56.0	57.5	21.0	44.8
	Mean	50.6	53.8	27.3	
F-test: Days (D), NS; Soaks (S), $P < 0.001$; D×S, $P < 0.001$; s.e. 1.03					
Blanch loss (%)†	0	25.0	15.0	12.5	17.5
	1	18.0	4.2	11.5	11.2
	2	16.5	+1.1	7.2	7.5
	3	12.8	+3.6	7.8	5.7
	Mean	18.1	3.6	9.7	
F-test: D, $P < 0.001$; S, $P < 0.001$; D×S, $P < 0.001$; s.e. 0.75					
Retort loss (%)	0	10.4	11.5	13.0	11.6
	1	12.8	14.5	11.4	12.9
	2	12.7	16.3	14.5	14.5
	3	13.8	16.4	12.8	14.3
	Mean	12.4	14.6	12.9	
F-test: D, $P < 0.001$; S, $P < 0.001$; D×S, $P < 0.01$; s.e. 0.45					
Total loss (%)‡	0	33.0	25.0	23.5	27.2
	1	29.5	20.0	23.0	24.2
	2	29.5	18.5	23.5	23.8
	3	28.5	17.0	23.0	22.8
	Mean	30.1	20.1	23.3	
F-test: D, $P < 0.001$; S, $P < 0.001$; D×S, $P < 0.001$; s.e. 0.44					

*See Materials and methods.

†Based on weight after chill storage.

‡Comprises weight loss during chill storage, blanching and retorting.

greatest for the 1% XVT in mushrooms chilled for 1–3 days (Table 2); chilling had a smaller effect on retort loss in mushrooms from the WVT and the 72 hr 3S treatment. Total weight loss comprises weight loss during chill storage, blanching and retorting. The data (Table 2) show that the 1% XVT gave the lowest total weight loss in mushrooms chill stored for 1–3 days but not in day 0 samples; the effect was largest in mushrooms chilled for 3 days prior to processing i.e., the 1% XVT had a total weight loss value 6% lower than the 72 hr 3S process and 11.5% lower than WVT samples. These data show the very pronounced effect of xanthan gum in reducing total weight loss in canned mushrooms.

Table 3. Whiteness and shear press values for canned mushrooms which were held for 0–3 days in chill storage (2–4°C) prior to canning

Factor	Days stored in chill prior to processing*	Soak treatment*			Mean
		Vac. soak water	Vac. soak 1% xanthan	3S soak	
Whiteness (Hunter L)	0	72	71	67	70
	1	71	72	67	70
	2	70	72	64	68
	3	69	70	61	67
	Mean	70	71	65	
F-test: Days (D), $P < 0.001$; Soaks (S), $P < 0.001$; D×S, $P < 0.01$; s.e. 0.50					
Shear press value (kN)	0	0.75	0.68	0.84	0.76
	1	0.83	0.75	0.87	0.81
	2	0.89	0.83	0.94	0.88
	3	0.90	0.81	0.96	0.89
	Mean	0.84	0.76	0.90	
F-test: D, $P < 0.001$; S, $P < 0.001$; D×S, NS; s.e. 0.02					

*See Materials and methods.

The total weight loss data must be viewed together with the whiteness results (Table 3). Chill storage prior to processing had no adverse effect on the whiteness of the WVT or XVT samples but there was a progressive decrease in whiteness of the 72 hr 3S canned samples as the length of the chill storage period prior to processing increased from 1 to 3 days. A Hunter L reading of 70 or above indicates a canned product with an excellent bright colour (white/yellow). The data (Table 3) show that the 1% XVT canned samples had an excellent colour in addition to their favourable total weight loss values. There was no significant day×soak treatment interaction in the case of mushroom shear values (Table 3). Chill storage for 0–2 days prior to processing increased shear values of canned mushrooms from the three soak treatments; however, chill storage for an extra day i.e., 3 days had no further effect on texture. The 1% XVT samples had the lowest shear values.

Experiment 3: Long term colour and shrinkage test

Mushroom shrinkage in-can was lower ($P < 0.001$) at the higher SMBS levels (Table 4) but this may be a function of blanching losses as well as SMBS level since blanching and retort losses are inversely related. Time of testing also influenced ($P < 0.01$) in-can shrinkage but the effect was inconsistent, being highest at the first and third dates and lowest at the second and fourth (Table 4).

The 0.10% SMBS level gave the best coloured mushrooms (Table 4); 0.25% SMBS gave equally white mushrooms early in the trial but in the later stages it was responsible for in-can de-tinning which discoloured the mushrooms (see significant interaction, Table 4); mean Hunter L values for the mushrooms 'ex-can' from this treatment fell from 73 on 18 May (1984) to 66 on 15 February (1985). The extent of the de-tinning is evident from in-can Hunter L reflectance values which ranged from 24 in the zero SMBS treatment to 9 in the 0.25% SMBS treatment. Some de-tinning also took place at the other SMBS levels (Table 4), suggesting that lacquered cans are needed when using even low levels of SMBS.

Table 4. Long term quality tests on canned mushrooms, treated with 1% xanthan gum solution containing different levels of sodium metabisulphite

	Sodium metabisulphite (%)*					
Factor	0.00	0.05	0.10	0.25	*F*-test	s.e.
Shrinkage (%) in-can	11.6	12.9	10.7	10.6	$P < 0.001$	0.32
Mushroom whiteness (L)	58	64	71	71	$P < 0.001$	0.45
Shear value (kN)	0.80	0.76	0.74	0.66	$P < 0.001$	0.02
SO_2 in mushrooms (mg/kg)	0.00	1.00	2.92	39.30	$P < 0.001$	0.67
pH of can liquor	5.4	5.3	5.3	5.4	$P < 0.001$	0.02
Can reflectance (L)	24	22	18	9	$P < 0.001$	0.30
	Testing date†					
	18 May	7 July	30 Nov	15 Feb		
Shrinkage (%) in-can	12.1	10.8	12.0	11.0	$P < 0.01$	0.32
Mushroom whiteness (L)	65	65	68	65	$P < 0.001$	0.45
Shear value (kN)	0.75	0.74	0.73	0.74	NS	0.02
SO_2 in mushrooms (mg/kg)	12.42	10.50	10.08	10.25	NS	0.67
pH of can liquor	5.3	5.3	5.4	5.4	$P < 0.001$	0.02
Can reflectance (L)	—	—	19	18	$P < 0.01$	0.21

Significant interactions: test date×sodium metabisulphite
Mushroom whiteness, $P < 0.001$
SO_2 in mushrooms, $P < 0.001$
Can reflectance, $P < 0.05$

*Means over four testing dates.
†Means over four SMBS levels.

The use of increasing amounts of SMBS resulted in a softening in mushroom texture (Table 4) and the effect was greatest between the 0.1 and 0.25% levels. However, no changes in texture took place between the first and last testing dates (Table 4). The amount of SMBS used significantly ($P < 0.001$) affected the pH of the can liquor, as also did ($P < 0.001$) time of testing (Table 4), but in practical terms the differences were very small and were no greater than 0.1 of a pH unit. Levels of SO_2 in the canned mushrooms were either zero or small for the 0.05 and 0.1% SMBS treatments; however mushroom SO_2 content was about 39 mg/kg for the 0.25% SMBS level (interaction, $P < 0.001$) with values of 46, 42, 37 and 32 mm/kg of drained mushrooms on the four testing dates respectively.

Discussion

The total loss value (blanch loss plus retort loss) of about 20% in the 1% XVT canned mushrooms corresponds to an increase of 23% in weight retention compared with the control and is similar to the value found by Singh *et al.* (1982) using 1.5% carboxymethylcellulose rather than xanthan gum. The 1% xanthan treatment compared favourably with the 72 hr 3S process in terms of weight retention in the mushrooms. The XVT mushrooms were whiter and had a more acceptable texture than 3S treated mushrooms and the time for vacuum treating with xanthan gum (0.5 hr) is much shorter than the long soaking and chill storage times required in the 3S process. The advantage of xanthan treatment is even more striking in view of the fact that the 3S process gives relatively low total loss canning values in comparison with other mushroom canning procedures (Gormley & Walshe, 1982; Beelman *et al.*, 1973; Parrish *et al.*, 1974; Beelman & McArdle, 1975). While the results showed that the 1% XVT gave a considerably lower total loss value in the canned product than 0.5% XVT, cost considerations may also be a factor in deciding the concentration of the xanthan gum solution to be used. A 1% xanthan gum solution is also quite viscous and could present problems during soaking and blanching of mushrooms on an industrial scale. The softening effect of the XVT on canned mushroom texture is a desirable feature as canned mushrooms often have a 'leathery' texture; a similar effect on texture was found in xanthan treated frozen mushrooms (Gormley, 1984). The ability of xanthan gum to reduce shrinkage in canned mushrooms is due, presumably, to its hydrocolloid nature. Some of the xanthan gum may also be bound by the mushroom protein, thereby preventing expulsion during blanching and retorting; Magsam (1977) has shown that xanthan gum can become bound to dairy proteins under certain conditions.

The XVT had an even more marked effect on weight retention in the canning of mushrooms which were chill stored prior to processing (experiment 2). The water uptake data post-chilling suggest that the mechanism by which water is soaked up in the 3S process (water binding by protein has been suggested by Eby, McArdle & Beelman, 1977) changes during the chill storage of the mushrooms; the same held true for the vacuum soak treatments except the effect was the opposite, i.e., chill storage enhanced the uptake. The increased water/solution uptake by WVT or XVT mushrooms with time of post-harvest storage was not 'making up' for water loss during chill storage as the increased uptake was larger than the water loss during chill storage. The net gain in weight after blanching 1% XVT mushrooms (blanching data based on mushroom fresh weight; not on weight after vacuum treatment) agrees with previous data from this laboratory on blanching/xanthan treatment (Gormley, 1984) and is also similar to the findings of Ferguson & Malick (1983) who reported (in a U.S. patent) blanching losses/gains in the range 2% loss to 5% gain for freshly harvested mushrooms subjected to a modified atmosphere and infused with a suspension containing a particulate microscopic heat stable material. Increasing lengths of chilling prior to blanching also reduced blanching losses in WVT and 3S process mushrooms but to a lesser extent. These reductions in blanching loss with increasing time of chilling pre-processing were paralleled by increased retort losses in most cases. The 1% XVT treated mushrooms had the highest retort loss and the lowest blanching loss. However, the overall beneficial effect of the 1% XVT was retained as shown by the total weight loss (during chill storage, blanching, retorting) values; these decreased with increasing time of chill storage and the effect was larger than that found by Beelman & McArdle (1975) for mushrooms stored for 1–3 days at 2°C and canned without any pre-soak treatment.

The poor whiteness values for pre-chilled 3S processed canned mushrooms relative to the XVT treated samples was expected in view of the long time involved before blanching in the 3S process; for example if the mushrooms are chill stored for 3 days prior to the commencement of the 3S process this results in a 6 day interval between harvesting and blanching i.e., 3 days for the chill storage and 3 days for the soak–chill–soak treatments of the 72 hr 3S process. Inevitably this will cause a loss in product whiteness despite the presence of 0.25% SMBS in the soak waters.

The data from experiment 3 indicate the desirability of using SMBS to maintain a good appearance in canned mushrooms. A level of 0.1% SMBS, or below, in the pre-blanch soak water/solution is desirable. Sodium metabisulphite had a softening effect on canned mushroom testure; this effect was also observed in frozen mushrooms treated, pre-blanching, with SMBS (Gormley, 1984). There were no consistent trends in mushroom shrinkage (in-can) during storage at ambient temperatures over a 9 month period; it was felt that the weight conserving effect of the xanthan gum in the canned mushrooms might change over time resulting in an increase in the loss of water and in the leaching of solids in the mushrooms. However, this did not occur.

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