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**Authors(s)** | Gormley, T. R. (Thomas Ronan); Walshe, P.E.  
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Frozen French fried mushrooms

T. R. Gormley and P. E. Walshe
Kinsealy Research Centre
The Agricultural Institute
Dublin 5, Ireland

ABSTRACT
Mushrooms were soaked in water or salt solution covered with batter, French fried and then blast frozen. Average weight loss/gain for the process for water soaked mushrooms (6 hr soak) was nil. The frozen product had a high quality shelf life of at least 9 months. Samples French fried and frozen within 2 hr of picking had a better flavour and softer texture than those kept at 18°C and processed 24 hours later. French fried mushrooms that had been soaked in water or salt solution had a better flavour and texture than unsoaked ones. If the amount of batter used was increased an overall gain in mushroom weight for the process was obtained. However, product acceptability was adversely affected.

Alternatively, the mushrooms can be soaked, coated with batter and then frozen. This results in a significant gain (up to 89% of initial weight) to the processor since the weight loss encountered at the frying stage is now passed on to the consumer. The quality of this product was tested after 4 months and was satisfactory.

1. INTRODUCTION
A major problem in the processing of mushrooms is the large loss of product weight due to blanching and retorting. In canning, the loss is usually between 30 - 40% (McArdle and Curwen, 1962). Gormley (1972) has reported blanching losses of 33% in the freezing of mushrooms. He stated that the blanching step could be omitted provided the mushrooms were packaged immediately after freezing and provided that deep freeze conditions were excellent throughout the cold chain; otherwise the product turned brown due to enzyme action. In practice it would be difficult to satisfy these conditions. McArdle and Curwen (1962), Bradley (1970) and Beelman (1973) have studied the influence of post harvest storage and soaking treatments on the yield and quality of canned mushrooms. Some of the treatments have been moderately successful in increasing the yield of the canned product.

This paper reports investigations on the production of frozen French fried mushrooms. The mushrooms are soaked in water or salt solution, covered with batter, fried and then frozen. Alternatively, the product is frozen after covering
with batter and the frying step is left to the consumer. This results in a large gain in weight for the processor. The flavour of the product can be varied by using soaking solutions of varying strengths (higher salt levels more desirable) and also different batter formulations. Texture can be influenced depending on the age of the mushroom post harvest and also by the length of soaking time.

2. EXPERIMENTAL

2.1. Soaking treatments

2.1.1. Test 1

Weight gain in different solutions: Batches (250 g.) of button mushrooms harvested 0 and 24 hours were soaked in salt solutions (0, 1, 2, 3% w/v) for 2, 4, or 6 hours and the gain or loss in weight for each batch was calculated. The tests were carried out four times using mushrooms from a different flush each time.

2.1.2. Test 2

Loss of hydration during frying: Freshly harvested button mushrooms (250 g. lots) were soaked in water for 0, 3 and 6 hours. The increase in weight due to hydration was calculated. The same amount of batter (fine flour - egg - milk) was then applied to each lot and they were fried. The mushrooms were weighed again and the loss of water (previously gained during soaking) was approximated by subtraction.

2.1.3. Test 3

Effect of soaking in different salt solutions on flavour: Mushrooms soaked for 2 hours in 2% w/v sodium chloride solution (covered with batter and fried) were compared with those soaked in water for a similar period by a 20 member taste panel. In a subsequent test, mushrooms soaked for 2 hours in 0, 0.5, 1.5 and 4.5% salt solutions were battered, fried and compared by a taste panel using a ranking procedure (Kramer and Twigg, 1966).

2.1.4. Test 4

Effect of soaking time on flavour and texture: The flavour and texture of mushrooms soaked in water for 0, 1 and 2 hours and then French fried was compared by a 10 member taste panel.

2.2. Batter application

Two different batter formulations were tested:

(a) Fine flour - whole egg - milk

This batter is referred to as flour batter in this paper. After washing and/or soaking the mushrooms (250 g lots) were placed on an mesh tray and were sprinkled with flour. They were rolled continuously to ensure a uniform covering of flour. They were then submerged in liquid batter (1 vol whole egg to 6 vol milk) and were sprinkled with flour and rolled again. This coating was termed single batter. Some batches of mushrooms received double (extra dip in batter and flour) and treble (2 extra dips in batter and flour) coverings of batter to assess the acceptability of different batter thicknesses on product acceptability. Mushrooms coated with flour batter were not suitable for freezing in the unfried form.

(b) Crumb - dried powder batter

This was a commercial batter formulation (called commercial batter in this paper). The crumb (made from wheat and soya flour) had a much coarser particle size than the fine flour. The dried powder (dried egg and milk solids) was rehydrated by adding 453 g to 568 ml of water. This batter was applied using a commercial battering machine. The product was suitable for freezing in the unfried form since the coarse crumb reduced stickiness and aided handling.

2.3. Mushroom age and flavour, texture

The effect of mushroom age post-harvest on the flavour and texture of the French fried product was assessed. Batches of freshly harvested mushrooms and those picked 24 hours were covered with batter (flour), fried and then blast frozen. They were stored at minus 30°C for 30 days and were then reheated and tasted by a 20 member paired comparison taste panel.

2.4. Frying, freezing and reheating

The mushrooms coated with batter (flour) were fried in vegetable oil at 190°C for 4 - 6 minutes.
until golden brown. The product was cooled and blast frozen (0.5 hr at minus 30°C). Reheating (ready to eat) directly from frozen was achieved in 15 minutes in an oven preheated to 200°C.

The mushrooms covered with the commercial batter were frozen in the unfried state in liquid nitrogen in a commercial freezer (freezing time, 9 min).

2.5. Weight gains and losses

The gains or losses in mushroom weight associated with different aspects of the process were calculated.

2.5.1. Test 1

This test has been described already under section 2.1.2. The weight gain/loss was calculated after soaking, covering with single batter (flour), frying and freezing.

2.5.2. Test 2

Freshly harvested mushrooms were soaked in water and were then coated with commercial batter (single layer). The product was then frozen in liquid nitrogen without prior frying. Weight gains were calculated for the process.

2.5.3. Test 3

The gains on losses in weight for freshly harvested and 1 day old mushrooms which were soaked in 2% NaCl for 2 hours, covered with single flour batter, fried and blast frozen were calculated.

2.5.4. Test 4

Freshly harvested mushrooms were soaked in 2% NaCl and were covered with single, double and treble flour batters. After frying and blast freezing the gains on losses in weight associated with the various stages were calculated.

2.6. Acceptability and shelf life

The shelf life of the frozen French fried mushrooms was tested after 3, 6, and 9 months by comparing them with samples prepared and frozen on the day prior to each test. The samples were heated directly from the frozen state in an oven at 200°C for 15 minutes. A 20 member paired comparison taste panel was used each time.

The unfried frozen product (coated with commercial batter) was removed from cold storage after 4 months and was fried directly from the frozen state. It was then compared with a freshly prepared sample by a 20 member paired comparison taste panel.

3. RESULTS AND DISCUSSION

3.1. Soaking tests

3.1.1. Test 1

Weight gain in different salt solutions: The results (Table 1) show that in general, uptake of solution was greatest at low salt concentrations and long times (6 hr). Some samples were left soaking for up to 9 hours but it was found that uptake tailed off after about 6 hours, even in pure water. Weight gains less than 10% can be considered in real terms as weight losses since mushrooms gain about 10% in weight on washing in water. Therefore, a loss of 9% is in reality 19%. Freshly harvested first flush mushrooms took up more water or salt solution than fresh mushrooms from flushes 2, 3 and 4 in every test. The uptake for mushrooms in flushes 2, 3 and 4 was about equal.

The larger gain in weight for day old mushrooms (at 4 and 6 hour stages) is due in part to the fact that the results are based on fresh weight at 24 hour post-harvest at which time the mushrooms had dehydrated to some extent. It is interesting to note that day old mushrooms gained less weight in the first two hours of soaking than the fresh ones and suggests that it took longer for the soaking process to get underway.

3.1.2. Test 2

Loss of hydration during frying: The results (Table 2, percentage values expressed in grams) show weight gains of 9 (due to washing), 34 and 39 g.
TABLE 1

Percentage gain or loss in weight for mushrooms left soaking in salt solutions (results averaged over four flushes)

<table>
<thead>
<tr>
<th>Soaking time (Hr.)</th>
<th>Salt conc (%)</th>
<th>Age of mushrooms post harvest (Hr.)</th>
<th>1</th>
<th>24(^1)</th>
<th>24(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>29</td>
<td>26</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>18</td>
<td>16</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8</td>
<td>9</td>
<td>-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>-9</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>40</td>
<td>52</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>23</td>
<td>33</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10</td>
<td>18</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>-7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>48</td>
<td>66</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>29</td>
<td>39</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10</td>
<td>21</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-3</td>
<td>7</td>
<td>-6</td>
<td></td>
</tr>
</tbody>
</table>

1 Calculated on mushroom weight 24 hr post harvest.
2 Calculated on mushroom weight 1 hr post harvest.

TABLE 2

Percentage of fresh weight remaining for mushrooms after soaking in water (0, 3 and 6 hr), covering with batter, French frying\(^1\) and freezing

<table>
<thead>
<tr>
<th>Soaking time (hr)</th>
<th>0</th>
<th>3</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>After soaking.</td>
<td>109(^2)</td>
<td>134</td>
<td>139</td>
</tr>
<tr>
<td>After covering with batter</td>
<td>129</td>
<td>157</td>
<td>161</td>
</tr>
<tr>
<td>After French frying.</td>
<td>93</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>After freezing.</td>
<td>91</td>
<td>101</td>
<td>100</td>
</tr>
</tbody>
</table>

1 Five minute frying time.
2 Weight gain during washing.

respectively for samples soaked 0, 3 and 6 hours in water. Batter pick-up was 20, 23 and 22 g. Weight losses on frying were 36, 52 and 56 g. Since the batter pick-up was approximately constant for the three samples, subtraction of the three weight gains during washing/soaking from the weight losses during frying gives relative values for absolute weight loss i.e. 36 - 9 = 27 g (wash only), 52 - 34 = 18 (3 hr soak) and 39 - 22 = 17 g (6 hr soak). This calculation shows that soaking contributes to weight after frying to the extent of about 10 g. This was borne out by the post-frying weight where soaked mushrooms were about 10 g heavier (Table 2). The 3 hour soak gave as good results as the 6 hour soak and the former soak time is, therefore, recommended.

3.1.3. Test 3

Effect of soaking in different salt solutions on flavour: Preliminary taste
panel tests on unsoaked French fried mushrooms indicated that salting improved the product. Addition of salt to the flour used in the batter made the batter oversalty, while the mushrooms themselves had not enough salt. Soaking mushrooms in a 2% NaCl solution for 2 hours before dipping in batter had the desired effect as indicated by a 15/5 (p = 0.05) preference ratio (20 tasters) for this sample over and unsalted one. The test was repeated using different salt solutions and the results (Table 3) show that samples soaked in a 4% salt solution were preferred.

**TABLE 3**

*Rank totals for saltiness of French fried mushrooms soaked in different sodium chloride solutions before frying (7 tasters and 4 samples)*

<table>
<thead>
<tr>
<th>Salt concentration (%)</th>
<th>Rank totals for saltiness</th>
<th>Number of tasters preferring each salt level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>27</td>
<td>-</td>
</tr>
<tr>
<td>0.5</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>1.5</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>4.0</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

1 Most saline sample ranked 1; least saline sample ranked 4. 2 Range for significance 10-25 (p = 0.01).

The panel had no difficulty in distinguishing between salted and unsalted samples, but they were not able to distinguish between mushrooms soaked in 0.5 and 1.5% salt solutions.

It should be stressed that soaking in salt solution is not essential and the French fried mushrooms which had been soaked in water were quite acceptable.

3.1.4. Test 4.

Effect of soaking time on flavour and texture: Rank totals for flavour of French fried mushrooms which had been left soaking in water for 0, 1 and 2 hours before frying were 25, 19 and 16 respectively (10 member panel, best sample scored 1). Even though this results is not significant (range 15 - 25 for p = 0.05) a trend exists favouring the longer soaking times. Panel members commented that mushrooms left soaking for 1 and 2 hours had a stronger aroma and more succulent texture after frying than those that were not soaked.

3.2. Batter thickness and product preference

Mushrooms which had been covered with single double and treble coatings of batter were assessed for acceptability by a 15 member taste panel. The rank sums for preference were 18, 34 and 38 for the single, double and treble batters respectively, indicating a significant preference (ranges 23 - 37 for p = 0.05 and 22 - 38 for p = 0.01) for mushrooms coated with a single batter. Panelists found that French fried mushrooms coated with a double or treble batter were too hard and there was an undesirable void between the batter and the mushroom.

3.3. Mushroom age and flavour, texture

Paired comparison taste panels (20 panelists) found that the French fried product made from fresh mushrooms had a better flavour than that made from mushrooms which had been harvested 24 hours (15/5 preference ratio p = 0.05). The texture of the latter was tougher than the former which agrees with work by
Gormley 1969, who found that freshly harvested mushrooms became increasingly tough for a period of about 5 days after harvesting.

3.4. Freezing and reheating
The French fried mushrooms were frozen satisfactorily using blast freezing methods. The product was free-flowing after freezing and this suggests that the slightly oily surface of the fried mushrooms was sufficient to prevent them sticking together during blast freezing. When reheating the frozen product it is important to adhere to the temperature (200°C) and time (15 minutes) fairly closely to obtain a product that is adequately warm at the centre. A low temperature or a short time results in a product that is still cold at the centre. At the other extreme, very high temperatures or a long time results in a dried-out over-crisp product.

3.5. Weight gains and losses
The loss of 'hydration' from mushrooms during frying has already been discussed in section 3.1.2. Most of the 'soaked water' was lost (Table 2). However, soaking did contribute to the frozen product weight by about 10%. In commercial terms this is a significant contribution. Freezing losses for soaked mushrooms were surprisingly large. This may have been due to the greater water content of the soaked mushrooms.

The gain in weight for mushrooms covered with the commercial batter and frozen in the unfried state was considerable. Average batter uptake was 43 g per 100 g fresh mushrooms, which was considerably higher than for the flour batter. This was due in part to the larger particle size of the crumb used in the commercial batter. If a 6 hour water soak is employed initially, an increase in weight of about 48% is obtained. A 100 g sample of fresh mushrooms would weigh 148 g after soaking. Batter pick-up raises this figure to 191 g (148 + 43). Freezing losses in liquid nitrogen were about 1% resulting in a final product weight of 189 g or 189% of the starting weight. If the product can be sold in the unfried form as seems possible from shelf life tests (Section 3.6.) - this gain in weight is of particular significance to the processor. In a further test (see section 2.5.3.) the weight loss during processing for freshly harvested and one day old mushrooms (covered with flour batter) was obtained. The results (Table 4) show that mushrooms which were one day old lost less weight on frying than freshly harvested ones - even when results for the former were calculated on the fresh weight at time of harvesting, (i.e. allowing for a 13.2% loss in moisture). On the basis of weight data it seems that day old mushrooms are a better proposition for French frying than freshly picked ones. This advantage is offset by the poorer flavour of the 'day old' mushrooms (Section 3.3.)

The results for weight gains and losses of mushrooms coated with single, double and treble coatings of batter are given in Table 5. As expected the mushrooms with the triple batter had the heaviest post freezing weight. Dehydration losses during frying were fairly similar i.e. 48, 40 and 42 units loss for single, double and treble batters respectively. This indicated that the heavier batters were having a slight sealing effect on moisture in the mushrooms.

3.6. Acceptability and shelf life
The shelf life of the frozen French fried mushrooms was tested after 3, 6 and 9 months. The preference ratios for the stored: freshly prepared samples were 15/5 (p = 0.05), 11/9 (NS) and 9/11 (NS) at the 3, 6 and 9 month stages respectively. These results show that frozen French fried mushrooms have a shelf life of at least 9 months.
TABLE 4

Percentage of fresh weight remaining for mushrooms after soaking in salt solution, (2 % for 2 hr) dipping in batter and French frying

<table>
<thead>
<tr>
<th>Age of mushroom</th>
<th>Freshly harvested</th>
<th>Harvested 24 hr&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Harvested 24 hr&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>After soaking.</td>
<td>108</td>
<td>110</td>
<td>96</td>
</tr>
<tr>
<td>After dipping in batter</td>
<td>127</td>
<td>133</td>
<td>116</td>
</tr>
<tr>
<td>After French frying</td>
<td>76</td>
<td>92</td>
<td>80</td>
</tr>
</tbody>
</table>

1 Six minute frying time.
2 Based on fresh weight 24 hr post harvest (loss of moisture 13.2 %).
3 Based on fresh weight at harvest.

TABLE 5

Percentage of fresh weight remaining for mushrooms after soaking in salt solution (2 % for 2 hr), covering with batter (single, double, treble), French frying and freezing

<table>
<thead>
<tr>
<th>Batter</th>
<th>Single</th>
<th>Double</th>
<th>Treble</th>
</tr>
</thead>
<tbody>
<tr>
<td>After soaking.</td>
<td>109</td>
<td>109</td>
<td>109</td>
</tr>
<tr>
<td>After covering with batter</td>
<td>129</td>
<td>142</td>
<td>155</td>
</tr>
<tr>
<td>After frying.</td>
<td>81</td>
<td>102</td>
<td>113</td>
</tr>
<tr>
<td>After blast freezing.</td>
<td>80</td>
<td>98</td>
<td>111</td>
</tr>
</tbody>
</table>

The flavour of the unfried frozen mushrooms was assessed after 4 months in cold storage by a taste panel. A preference ratio of 12/8 (NS) for freshly prepared mushrooms (20 member panel) was obtained. This was not a statistically significant result. However, some panelists felt that the flavour of the stored sample was too strong and two tasters commented that it was slightly off-flavoured. The off-flavour seemed to be in the mushroom rather than in the batter. It seems, therefore, that covering with batter and freezing without prior blanching or frying treatment may result in off-flavour problems. Further tasting tests will be carried out after 6 and 9 months frozen storage. The appearance of the product, both on removal from cold storage and after frying, was excellent.

4. CONCLUSIONS

The results presented show that processing mushrooms by covering with batter and freezing, or frying and then freezing, is a satisfactory process and overcomes the problem of large weight losses during processing. The product has an excellent flavour and appearance. It has added value and can be eaten as a hors d'oeuvre, as a vegetable, as a main course or as a snack food. However, the long term shelf life of the unfried frozen product has yet to be established.
5. ACKNOWLEDGMENTS

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6. REFERENCES


