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## **The Application of Freeze-Chill Technology to Ready-To-Eat Meal Components**

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**Abstract.** *Freeze-chilling involves freezing and frozen storage followed by thawing and chilled storage. A number of ready-to-eat meal components have been studied for their suitability for freeze-chilling including, potatoes, carrots, green beans, broccoli, salmon and white sauces. In general, sensory analysis showed that freeze-chilled products were similar in quality to their chilled or frozen counterparts. There were some differences between the freeze-chilled and chilled products in instrumental texture assessment and centrifugal drip loss due to cell damage arising from the freezing step. A freezing rate study was carried out to determine if more rapid freezing could improve texture and drip. Mashed potato was frozen at -30, -60 or -90°C to an internal temperature of -25°C, stored at -25°C for 4 days and then stored at chill temperature (4°C) for a further 4 days. No difference was found in sensory acceptability between any of the treatments. Drip loss was lower ( $P<0.001$ ) in the chilled mashed potato and decreased with decreasing freezing temperature in the freeze-chilled mashed potato. Freeze-chilling led to a firmer texture ( $P<0.001$ ) than chilling alone but the texture softened ( $P<0.01$ ) with decreasing freezing temperature. Freeze-chilled foods are potentially more at risk to temperature abuse than chilled products due to the increased amounts of drip water arising from the freezing/thawing steps. A trial was carried out on the effects of different storage temperatures on the quality and safety of freeze-chilled mashed potato. No difference in microbial levels was detected between chill and freeze-chill at any storage temperature but storage time and temperature had effects on total viable counts in both chilled and freeze-chilled products.*

**Keywords.** Freeze-chilling, potatoes, green beans, carrots, quality.

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## Introduction

The ready-meals market has grown significantly in Europe over the past decade with the chilled sector experiencing the most dynamic growth (Intel, 1997). The strong demand for products that are fresh, healthy, safe to eat and of good quality have particularly contributed to the growth within this sector (Mahon *et al.* 2000). Chilled ready-meals are perceived to be of better quality than frozen meals (Stringer, 1990). One of the main problems with chilled ready-meals, however, is their relatively short shelf-life and frozen ready-meals are bought more often due to their longer shelf-life (Mahon *et al.* 2000). Along with the advantage of extended shelf-life, frozen ready-meals also offer better manufacturing and distribution flexibility, food safety and extended storage time (Kobs, 1997).

Freeze-chilling is a dual process, which involves freezing and frozen storage followed by thawing and chilled retail display. It has an advantage over chilling as it allows bulk preparation of frozen products followed by controlled batch release of thawed product into the chill chain. It has a logistic advantage of enabling 'chilled' products to reach foreign markets more easily. Freeze-chilling can also reduce the level of product recalls as it enables routine microbiological tests to be completed before the product is released from the factory (Redmond and Gormley, 2001). Freeze-chilling has particular application to complex foods such as ready-meals or ready-meal components. However, all components must be freeze-thaw stable, including sauces and gravies. This may require the incorporation of functional ingredients, such as hydrocolloids.

Tests at The National Food Centre indicated that steamed salmon, steamed broccoli and reconstituted mashed potato are suitable products for freeze-chilling (O'Leary *et al.* 2000). The objective of the current study was to examine the effect of freeze-chilling on the quality of potatoes, carrots and green beans. The effect of different freezing rates and temperature abuse on the quality of freeze-chilled mashed potato was also examined.

## **Materials and methods**

### ***Sample preparation***

For the potato trial, approximately 1500g of potatoes (Rooster cultivar) were peeled, washed and diced (~2-3cm cubes). The potatoes were then boiled on a bench top electric hob oven (Model 9934, Russell Hobbs) until soft (~ 40 mins). Once cooked, the potatoes were mashed and transferred to plastic containers (500g per container) which were then subjected to one of the freezing/chilling treatments outlined below. For the carrots and green beans, approximately 350g of product was steamed in a domestic steamer (Tefal Steam Cuisine, Tefal U.K. Ltd., London, U.K.) for 20 minutes. Once cooked, the samples were then transferred to airtight containers and subjected to one of the freezing/chilling treatments outlined below. Reconstituted potato mash (Chivers Ireland Ltd., Dublin, Ireland) was used for the freezing rate trial. Once cooled to room temperature, samples of potato (130 g) were placed in plastic pots and subjected to different freezing rates outlined below.

### ***Freezing treatments***

For the potato trial, the potato was subjected to one of the following treatments:

**Treatment 1 *Freeze-chill*:** Product was blast frozen at -30°C for 2.5hrs, then stored at -25°C for 4 days, thawed overnight at 4°C and kept in chilled storage at 4°C for 4 days.

**Treatment 2 *Freeze*:** Product was blast frozen at -30°C for 2.5hrs and stored at -25°C for 4 days, then thawed overnight at 4°C.

**Treatment 3 *Chill*:** Product was placed in chilled storage at 4°C for 4 days

**Treatment 4 *Fresh*:** Product was cooked and tested on day of analysis

For the carrots and green beans, the products were subjected to the same treatments as the potato but the time in frozen and chilled storage was increased from 4 to 7 days.

For the freezing rate trial, the freezing stage of the freeze-chill process was carried out using a liquid nitrogen cryogenic environmental chamber (CM-2000, Carbueros Metalicos, Madrid, Spain). The pots of mashed potato were frozen at -30, -60 or -90°C to an internal temperature of -25°C, stored at -25°C for 4 days in a chest freezer and then thawed and stored at chill

temperature (4°C) for a further 4 days. A control consisted of mashed potato samples that had been chilled for 4 days at 4°C (i.e. no freezing step).

### ***Texture measurement***

For the potatoes a cylindrical probe ( $d$  12.5 mm) attached to a Kramer shear press (Allo Precision Metals Engineering Inc., Maryland, USA) was lowered (entry speed 4.5 mm/s; exit speed 5.5 mm/s; penetration depth 30 mm) into a pot containing 130 g ( $\pm$  1 g) of potato sample and the maximum penetration force (N) was recorded. For the carrots and green beans, texture was measured using a T 2000 Texture System (Food Technology Corporation, Maryland, USA) fitted with a standard Kramer shear cell (entry speed  $\sim$ 4.3 mm/s) using 100g of product. Measurements were made in duplicate on a single sample per treatment after chilled storage.

### ***Centrifugal drip loss***

Drip loss from the products was assessed after chilled storage by measuring the water loss after centrifugation according to the method of Anese and Gormley (1996). Approximately 3 g of product was accurately weighed into a paper filter thimble and placed in a centrifuge tube containing a layer of glass beads 20 mm deep. Samples were centrifuged at 223 x g for 10 min at 10°C using a MSE Mistral 3000I (MSE Ltd., Leicester, UK). After centrifugation the samples were removed and reweighed. Percentage drip loss was expressed as follows:

$$\text{Drip loss (\%)} = \frac{(w_i - w_f)}{w_i} \times 100$$

where  $w_i$  is the initial weight, and  $w_f$  is the final weight of the sample. Measurements were made in duplicate on a single sample per treatment.

### ***Taste panel acceptability***

Taste panel tests were carried out on the sample range after chilled storage. For each replicate, fifteen panellists, experienced in sensory analysis, were presented with four heated samples (approximately 20 g) per sitting, i.e. one sample from each of the four freezing/chilling treatments. The panellists were asked to score the samples on a 5 cm line scale (with no divisions) with end-points of 'unacceptable' (0) and 'very acceptable' (5). The point marked on the line by each panellist was measured and the mean score for each treatment was calculated.

## ***Vitamin C***

Vitamin C content was measured for the potato samples after chilled storage using the 2, 6 dichloroindophenol titrimetric method (FWTG, 1997). Measurements were made in duplicate on a single sample per treatment.

## ***Temperature abuse***

Pots of mashed potato were either freeze-chilled or chilled as described above and then stored at 4, 7 or 10°C for 8 days. TVC (total viable count) analysis was carried out on days 1, 4 and 8.

## **Results and discussion**

### ***Texture and centrifugal drip***

The texture of mashed potato is of critical importance to its acceptability, a soft mealy texture being preferred to one that is sticky, cohesive or gluey (Faulks and Griffiths, 1983). Shear force is a measure of firmness with a high value indicating a firm product. In the potato study, a significant difference in penetration force was found between treatments ( $P < 0.001$ ). Freeze-chilling and freezing led to a significant decrease in shear force (firmness) compared to chilling or preparing fresh. The texture of plant tissues is often damaged during freezing due to the physical effects of ice and also to chemical effects arising from concentration of solutes in the unfrozen phase (Fennema, 1993). A significant difference was also found in drip loss between treatments ( $P < 0.001$ ). Freeze-chilling and freezing led to significantly higher drip losses than chilled or fresh potato. Again this was due to cell damage due to ice crystal formation during freezing (Reid, 1990). Similar results for texture and drip loss were also found for carrots. However, freeze-chilling and freezing had no effect on the texture of green beans. This was unexpected as previous studies on broccoli and potatoes have found that freeze-chilling leads to a softer, less firm product than chilling or preparing fresh (O'Leary *et al.* 2000; Redmond *et al.* 2001). The standard deviation in the texture results was high and this may explain why no difference was found between treatments.

### ***Sensory analysis***

In general, sensory analysis showed that freeze-chilled products were similar in acceptability to their chilled and frozen counterparts. No significant difference was found in taste panel acceptability for potatoes (mean value = 2.6) or carrots (mean value = 2.8) between freeze-

chilling and the other treatments. O'Leary *et al.* (2000) found similar results for reconstituted mashed potato and broccoli. For green beans, the freeze-chilled product was more acceptable than the fresh product ( $P < 0.05$ ) (2.5 and 1.9 respectively) and similar to the chilled and frozen products (2.5 and 2.6 respectively).

For the freezing rate experiment, increasing the freezing rate had no significant effect on product acceptability (mean value = 2.18). Some authors have found that a faster freezing rate produces a high quality product (Novak and Ramachandra, 1966; Hill and Glew, 1973; Childers and Kayfus, 1982), whilst others have found that product quality is not influenced by freezing rate (Cunningham and Lohmeyer, 1972; Streeter and Spencer, 1973).

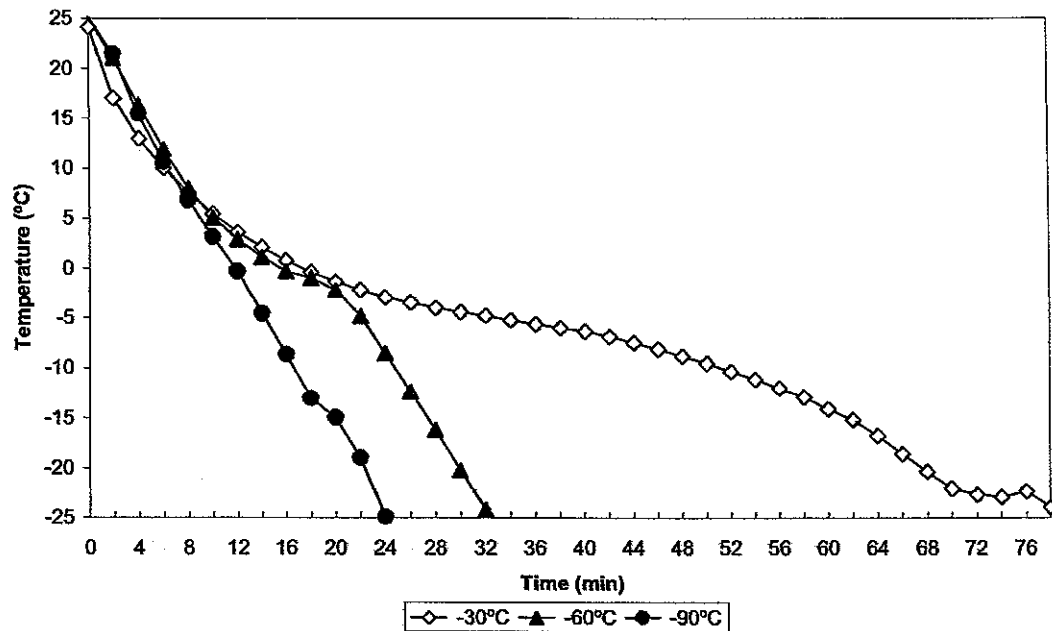
### **Vitamin C**

A significant difference in the vitamin C content of mashed potato was found between treatments ( $P < 0.001$ ). As expected the fresh potatoes had a higher vitamin C content (2.9 mg/100g) than all the other treatments. Chilled and freeze-chilled potatoes had the lowest vitamin C content (1.0 and 0.9 mg/100g respectively). This is consistent with other reports (Augustin *et al.* 1982; Bognar *et al.* 1990) which state that vitamin C loss is greater at chill temperatures. Several authors have found that vitamin C loss in vegetables during frozen storage is relatively small (Bender, 1993; Favell, 1998; Lisiewska and Kmiecik, 1996), whereas losses during chilling can be as high as 40% after 3 days in chilled storage (Williams *et al.* 1995). Increasing the freezing rate had no effect on the vitamin C content of reconstituted potato mash.

### **Freezing rates**

Figure 1 shows the core potato temperature profiles in the pots for the three different freezing regimes. As expected, the lowest freezing temperature (-90 °C) led to the fastest reduction in temperature ( $P < 0.001$ ). Faster freezing rates can result in a better quality product due to the formation of small intracellular ice crystals as opposed to large ones formed during slow freezing (Fennema, 1989; Karel *et al.* 1975; Scholey, 1970).



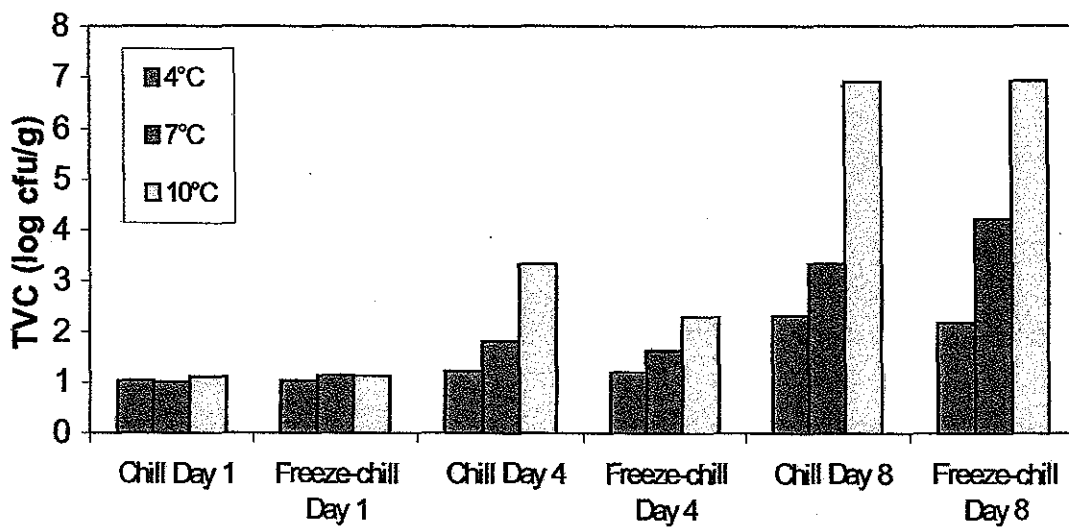


**Figure 1** Average core temperatures for reconstituted mashed potato during freezing at -30°C, -60°C, and -90°C

One of the major textural problems with reconstituted mash is stickiness/firmness. This may be due to an excessive amount of extracellular 'free starch' produced both by diffusion of starch through the cell walls during cooking and by rupture of the cooked cell walls during mashing and mixing (Faulks and Griffiths, 1983). Ice crystal formation during freezing leads to further destruction of cell walls and therefore more 'free starch'. This may explain why the frozen reconstituted mashed potato was firmer than the chilled reconstituted mashed potato. Lowering the freezing temperature resulted in a softer product, however the effect was non-linear. Drip loss was lower for the chilled reconstituted mashed potato (0.65%) than for the freeze-chilled samples (17%) ( $P < 0.001$ ). Drip loss decreased linearly ( $P < 0.001$ ) with freezing temperature (20.7% at -30°C, 18.1% at -60°C, 12.1% at -90°C). This was to be expected as faster freezing rates mean smaller ice crystals, less damage to the cell structure, and therefore less drip (IIR, 1986).

## Temperature abuse

The limiting factor for the shelf-life of freeze-chilled foods is usually the chill phase as chilled foods are particularly susceptible to microbial problems. Failure to maintain proper refrigeration is probably the single most cited hazard associated with chilled foods (Brackett, 1992). There is also a possibility that freeze-chilled foods could be more susceptible to microbial growth due to the presence of nutrients in the drip, and also because freezing may open up the cell structure. No difference in microbial levels was detected between chilled and freeze-chilled mashed potato at any storage temperature. Storage time (up to 8 days) had little effect on microbial count at 4°C (log 1 at day 1; log 2.3 at day 8) but led to increased growth at 7°C (log 1.1 at day 1; log 4.2 at day 8) and 10°C (log 1.1 at day 1; log 6.9 at day 8). As expected, increasing storage temperature (4°C to 10°C) led to a significant increase in microbial growth by day 4 of storage for both chilled and freeze-chilled mash (Fig 2). These results suggest that freeze-chilled products can be treated as chilled products during distribution and retail display.



**Figure 2** Effect of storage time and temperature on TVC values of freeze-chilled and chilled mashed potato

## Conclusion

In general, sensory analysis showed that freeze-chilled products were similar in quality to their chilled or frozen counterparts. There were some differences between the freeze-chilled and

chilled products in instrumental texture assessment and centrifugal drip loss due to cell damage arising from the freezing step. Increasing the freezing rate during freeze-chilling of reconstituted mashed potato led to a reduction in drip loss and a softer product. However, these differences did not impact on sensory analysis and, therefore, there is little advantage in using lower freezing temperatures. No difference in microbial levels was detected between chilled and freeze-chilled mashed potato at any storage temperature, which suggests that freeze-chilled products should be treated as chilled products during distribution and retail display. Storage time and temperature had an effect on total viable counts in both chilled and freeze-chilled products and careful temperature control should be exercised to ensure the quality and safety of these products. Overall, results showed that freeze-chilling has potential to improve the flexibility of production for many ready-meal components.

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