Changes in the nutritional content of fruit and vegetables during the dehydration process of freeze drying

— A Chaucer Foods comparative study of total antioxidant capacity, total phenolics and Vitamin C content.

October 2013
Introduction

This paper presents the results and findings of a study into the stability of certain nutritional components contained within selected fruit and vegetables during the process of dehydration by freeze drying. The research was a collaborative study between Chaucer Foods Ltd (CFL) and Sheffield Hallam University (SHU) in the UK. The investigation took place in Summer 2013. The key nutritional variables investigated during the study were: Vitamin C content, total phenolic content and total antioxidant capacity. The fruits and vegetables used to undertake the analysis were: strawberry (whole and sliced), lime, orange, blackcurrant, broccoli and red bell pepper. Details of the background to the study, methodology, findings and conclusion are provided below.

Key results and conclusions

The study found that freeze dried whole strawberries had no recorded loss of Vitamin C and total phenolic content and only an 8% loss in total antioxidant capacity (TAC). However, for equivalent chilled whole strawberries stored over seven days, there were significant losses for Vitamin C content (-19%) and TAC (-23%) and a very significant loss in total phenolic content (-82%).

The study also found that the freeze drying process has little or no detrimental effect on the total antioxidant capacity, total phenolic content or Vitamin C content of other fruits and vegetables which were tested.

Background

Freeze dried fruits and vegetables have been used by the global Food Industry for many years. Freeze dried vegetables have been widely used in dried soups and dried meals particularly in Asia. More recently freeze dried fruits have been included in healthy breakfast cereals and some cereal bars. Other uses for fruit are in premium chocolate confectionery and speciality beverages such as fruit teas and other hot and cold drinks.

In the last 2 years, a significant market has grown in the use of freeze dried vegetables and fruits positioned as healthy snacks. This has been particularly prevalent in North America. Many are marketed to children and health-aware adults. These products sit alongside a diverse range of fruit-based products loosely categorised as fruit snacks. Many are targeted at children and claim to offer a single portion of fruit as part of one of 5-a-day intake as recommended by governments. These products are mainly produced using alternative drying technologies such as air drying and sugar infusion. The adverse effect of these technologies on nutrient retention is well documented. Studies undertaken by Chaucer Foods on strawberry drying using these alternative methods highlighted a significant loss in their nutrient content in terms of Vitamin C level.

In recent years, food manufacturers have become increasingly focused on the nutrient content of their products driven by consumer requirements for natural and nutritious, ‘good-for-you’ foods. At the same time, compelling evidence from numerous medical-related studies has stressed the importance of eating fruit and vegetables to help protect the body from chronic disease.
Fruits and vegetables are sources of many vitamins, minerals and other natural substances (phyto-chemicals) that have numerous functions in the human body.

Vitamins are organic substances essential to life that must be present in the diet in very small amounts to generate energy, promote growth, maintain and repair the body and for many metabolic processes. 13 vitamins are essential. The body cannot produce these so they must be consumed in the diet.

Phytochemicals (or phytonutrients) are compounds that are not required for the normal functioning of the body, but have a beneficial effect on health or an active role in the improvement of a disease-caused condition. Thus they differ from what are traditionally termed nutrients in that they are not a necessity for normal metabolism and their absence will not result in a deficiency disease, at least in the short term.

This study has focused on 3 measures of nutrient value:

- Total vitamin C content.
- Total phenolic content.
- Total antioxidant activity.

Vitamin C, also known as ascorbic acid has several important functions. It is necessary for the maintenance of healthy connective tissue which gives support and structure for other tissue and organs. It helps in wound healing. Vitamin C is also one of many antioxidants. These are nutrients that block some of the damage caused by free radicals. The latter are formed when the body breaks down food. The build-up of free radicals overtime is largely responsible for the ageing process. Also, free radicals may play a role in cancer, heart disease and conditions like arthritis. Many fruits and vegetables are high in Vitamin C.

Phenolic compounds (or polyphenols) comprise a large category of phytochemicals that include flavonoids (the largest group) and phenolic acids. The phenolics group is so large that it is difficult to generalise their health benefits. However dietary phenolics are strong antioxidants. Most highly coloured fruits and vegetables supply phenolics.

Total antioxidant capacity is the term used to describe the total capacity of antioxidants in different foods known for cleaning harmful free radicals in the blood and cells. Often referred to by the acronym TAC, total antioxidant capacity takes into account the amount of water-based and fat-based antioxidants present in food.

“In recent years, food manufacturers have become increasingly focused on the nutrient content of their products driven by consumer requirements for natural and nutritious, ‘good for you’ foods”
The freeze drying process

Freeze drying is one of a number of dehydration technologies used to remove water from food. Freeze drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublime directly from the solid to the gas phase.

There are a number of intuitive reasons to suggest that freeze drying should minimise the breakdown and degradation of nutritional components such as Vitamin C.

- The colour and flavour of fruits and vegetables are maintained during freeze drying (indicating chemical stability).
- The freeze drying process is used to preserve and store sensitive biological products such as blood serum (chemical stability).
- Living bacteria survive the freeze drying process (biological stability).

The physical conditions within the process do not require exposure of the dehydrate to prolonged periods of high temperature.

- Typical starting temperature for the process is around -25°C.
- Final product temperature in the process rarely exceeds 60°C.
- Sublimation and dehydration takes place in a vacuum, without the presence of oxygen.

Literature review of related studies

As part of the study, a literature review was undertaken. This revealed that there was little comparative data available from similar studies. Whilst several studies have been undertaken, there is no depth of research on any particular type of fruit and vegetable to demonstrate generically that freeze drying preserves key nutritional components such as antioxidants, total phenolics and Vitamin C.

**Yurdugul S (2006)** – *An evaluation of the retention of quality characteristics in fresh and freeze dried alpine strawberries.* International Journal of Food Science and Technology 2008, 43, 865-870. The results of a study on the effects of the freeze drying process on the characteristics of alpine strawberries, such as firmness, sugar content, pH, colour, weight loss, dissolved solids, anthocyanin and Vitamin C content with reference to the fresh was reported. Freeze drying indicated no difference in the characteristic of the alpine strawberries when compared with the fresh.

**Sablani S et al (2011)** – *Effects of air and freeze drying on phytochemical content of conventional and organic berries* [on line] Drying Technology, 29 205-216. This study was an evaluation of air and freeze drying on conventional and organic red raspberries and blueberries. Total anthocyanin, phenolic content and total antioxidant activity were determined in various varieties of blueberry and raspberry. The study determined that freeze drying improved the retention of phytochemicals during processing and on occasion increased the phenolic content in both red raspberries and blueberries by 17%-52%.

“The colour and flavour of fruits and vegetables are maintained during freeze drying”
Methodology

The methodology used for the study was as follows:

• A range of fruits and vegetables was selected for analysis and sourced from a local retailer close to Sheffield Hallam University.

• Each material was divided into 2 groups – A and B.

• Group A material was immediately stored under chilled conditions.

• Group B material was immediately frozen and freeze dried.

• Both A and B group materials were subsequently analysed for moisture content, Vitamin C content, total phenolic content and TAC.

• Theoretical and actual concentrations effects due to the freeze drying process were computed and changes in nutritional variables evaluated.

Methods of analysis to measure nutritional variables in chilled and freeze dried product were:

• TAC – The OxiSelect™ TAC Assay Kit

• Total phenolic content – The Folin-Ciocalteau Method with slight modification.

• Vitamin C – BioVision’s Ascorbic Acid Assay Kit.

Location of testing

The majority of testing was undertaken on Sheffield Hallam’s test freeze drier located at the university.

Parallel testing was conducted on freeze dried strawberries at Sheffield Hallam University and Chaucer Food’s pilot freeze drier based in its factory in Saumur, France. A common raw material was used in both locations.

Significance

Each test was undertaken 5 times (n=5), designed to give a confidence level of 95%. The data presented in the findings section therefore represent the average of 5 replicates. The results are significant at P<0.05.

Selection of fruits and vegetables for analysis

The following products were used for analysis:

• Whole strawberry
• Lime
• Strawberry slices
• Red bell pepper
• Blackcurrant
• Broccoli
• Orange

All products were sourced as fresh material from a local retailer, excluding blackcurrant which was supplied in a frozen format due to lack of local availability.

Special focus was given to strawberry given its commercial importance as the largest volume item in terms of freeze dried global production.
The chart indicates that there is some loss of TAC comparing fresh and freeze dried material for both strawberry slices and whole strawberry (freeze dried at SHU and at Chaucer Food’s pilot plant). After 7 days chilled storage, the loss in TAC was 22.7%.

The chart details changes in TAC for other fruits and vegetables. In most cases the losses are relatively small. Lime 2.7%, Orange 0.3%, Blackcurrant 0.6%. No change in TAC was found for broccoli however the loss for red bell pepper was more significant at 27.3%. TACs for broccoli for fresh and freeze dried material were by far the largest values.

For other fruits and vegetables, no loss was recorded for lime and blackcurrant, and small losses were recorded for orange at 1% and red bell pepper at 5%. The apparent increase in phenolic content for broccoli is an anomaly at this stage and requires further investigation.

The chart indicates that there is no loss in phenolic content comparing fresh and freeze dried material for both strawberry slices and whole strawberry (freeze dried at SHU and at Chaucer Food’s pilot plant). However the loss in phenolic content in chilled strawberry after 7 days was very significant, recording a 82.2% reduction.

The chart indicates a no loss in vitamin C content for freeze dried material (SHU or Chaucer Food’s pilot plant) compared to fresh product for whole strawberry and a slight loss for sliced strawberry of 3.3%. After 24 hours, the chilled material had lost 9.2% of Vitamin C content rising to a 19% loss after 7 days.

For other fruits and vegetables, most products lost some Vitamin C content comparing fresh and freeze dried material. For lime the loss was 13.3%, orange 6%, blackcurrant 1% and broccoli 4.3%. No loss in Vitamin content was recorded for bell pepper and broccoli.

**Total phenolic content**

<table>
<thead>
<tr>
<th>Treatment (Strawberry Variety - ELSANTA)</th>
<th>Fresh</th>
<th>Chilled (24hr)</th>
<th>Chilled (7 Days)</th>
<th>F-D Sliced (SHU Dried)</th>
<th>F-D Whole (Chaucer Trial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phenolic Content (mg/L Gallic Acid Equivalents)</td>
<td>625</td>
<td>675</td>
<td>120</td>
<td>679</td>
<td>679</td>
</tr>
</tbody>
</table>

**Vitamin C content**

<table>
<thead>
<tr>
<th>Treatment for Strawberry Variety - ELSANTA</th>
<th>Fresh</th>
<th>Chilled (24hr)</th>
<th>Chilled (7 Days)</th>
<th>F-D Sliced (SHU Dried)</th>
<th>F-D Whole (Chaucer Trial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C Content (nmol Ascorbate) vs Treatment</td>
<td>208</td>
<td>208</td>
<td>178</td>
<td>223</td>
<td>290</td>
</tr>
</tbody>
</table>

**Conclusion**

This study has focused on the effects of dehydration by freeze drying on a number of fruits and one vegetable. It supports evidence in other investigations that dehydration by freeze drying is relatively nutrient friendly because the nutritional loss in terms of Vitamin C content, total phenolic content and antioxidant capacity is relatively small.

Further studies are planned to compare the nutrient retention of freeze dried fruit and vegetables against those that have been dried using alternative technologies, and also to consider the effects of packaging and storage on nutrient retention following the freeze dried process.