UNIVERSITEIT GENT

FACULTY OF BIOSCIENCE ENGINEERING

Department of Food Safety and Food Quality
Laboratory of Food Technology and Engineering

OEITFL BIBLIOGRAPHICAL STUDY ON THE NUTRITIONAL BENEFITS OF PROCESSED FRUIT & VEGETABLES

Addendum 2007 summaries

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1. INTRODUCTION

This 2007 Addendum updates the OEIFTL Bibliographical study with the most recent scientific research data on the nutrient content of common vegetables and fruits, as consumed.

The previously used report strategy was maintained: the updated vegetable and fruit tables and summaries compare the nutritional value of products consumed fresh with that after frozen or canned storage and after appropriate boiling or cooking. For fruits, the manufacture of jam was also included.

Again special attention is paid to vitamins, such as vitamin C and folic acid, dietary fibre, and other bio-active substances known for health-promoting properties, such as phenolic compounds.

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2. IN GENERAL

1. Upon analysis of literature data, it is evident that processes like canning, blanching, freezing, thawing and drying result in some losses of nutrients. This is however also the case for ambient or chilled storage of fresh products and for food preparation processes like boiling, steaming, microwave heating and equivalent.

2. Retention of nutrients depends upon many factors:
   - the type of processes, particularly the leaching effects and the time / temperature applied,
   - storage conditions,
   - the stability of the nutrient,
   - the type of fruit or vegetable: the structure, the distribution of nutrients, the presence of a protective skin and others,
   - the interactions between nutrients.

3. Stability of nutrients is rather variable. Water soluble vitamins are most sensitive to losses. Fat soluble vitamins are somewhat more stable.
   The concept of indicator vitamins, like vitamin C and folic acid remains valid. They are a criterion to assess the effect of a particular process as they are the most sensitive constituents.

4. When studying nutrients in processed fruits and vegetables, garden fresh products are very often taken as a reference. This is a rather unrealistic comparison as fresh products are in most cases not garden fresh; they reach the consumer after a significant time period. There is ample evidence that during this ambient or chilled storage important losses may occur. For that reason fresh products as obtained by the consumer at the retail level are lower in nutrient levels than garden fresh products. It has also to be mentioned that literature data are often not very specific with respect to the harvest period.

5. Data found in national food tables are to some extend misleading as they compare also in some cases garden fresh products with processed ones. In rare cases values are given for fresh products at the end of the retail system.

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6. It is clear that the only valid procedure is to compare products as eaten (on the plate). In this case the nutrient content of products obtained by the fresh route is not always higher than processed ones. If processes are optimized nutrient retention is rather high but major losses occur during food preparation.

7. In recent years more data has been published concerning home processing of vegetables. Reheating processes like boiling, stir-frying and micro-waving of fresh and frozen vegetables have been compared. Heating processes using a minimum amount of water like micro-waving and in some cases stir-frying with oil are recommended to prevent vitamin destruction. Frozen vegetables should also not be thawed before cooking.

8. With respect to nutrients it self, vitamins are most studied and are most sensitive to degradation. Fat soluble vitamins are more stable than water soluble. Minerals and trace elements are less affected. If losses occur of these constituents, leaching is the determining factor. Information on constituents like dietary fibre is still limited. Small effects of heating on fibre are mentioned, particularly a redistribution of soluble and insoluble fibre fractions. Studies are limited to total fibre or to fibre fractions. Information on the effect of processing and preparation on individual fibre constituents is scarce. Over the last few years more and more research was published on the effect of processing upon antioxidants like bio-active phenolic compounds. Some research groups demonstrate that processing of vegetables results in higher antioxidant activities due to the increased release of bound phenolic compounds, despite the loss of other vitamins. Depending on product, processing parameters and methods, thermal processing may enhance, reduce or cause no change in antioxidant capacity.

9. A high dietary intake of vegetables and fruits as a source of vitamins, antioxidants, dietary fibre and phenolic compounds is associated with protection against a broad range of human chronic diseases like cancer and heart disease.

10. The effect of processing on natural anti-nutrient factors like lectins has not been thoroughly studied, with the exception of dry pulses. These products are however out of the scope of this study. It is known that some of these factors are present in fresh products. Some beneficial effects may be expected on the inactivation of these factors, particularly by heating.

10. Even less information is available on the effect of processing on bioavailability of nutrients e.g. vitamins. Further studies are needed to evaluate the stability of anti-nutritional factors and the interactions between anti-nutritional factors and nutrients during processing, to find

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suitable techniques to measure bioavailability as well as evaluating the influence of processing on improving the bioavailability of nutrients in vegetables and fruits (e.g. lycopene in tomato).

11. As an overall conclusion it can be said that processed fruits and vegetables contribute in a significant manner to the intake of essential nutrients in our daily diet. This conclusion is even more valid when they are compared with fresh products after food preparation.

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VEGETABLES

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3. REFERENCE LIST VEGETABLES

Agostini, L.R., Jimenez, M.J.M., Ramon, A.N. & Gomez, A.A. (2004). Determinacion de la capacidad antioxidante de flavonoides en frutas y verduras frescas y tratadas termicamente. *Archivos Latinoamericanos de Nutricion*, 54, 89-92.

Amin, I., Zamaliah, M.M. & Chin, W.F. (2004). Total antioxidant activity and phenolic content in selected vegetables. *Food chemistry*, 87, 581-586.

Andlauer, W., Stumpf, C., Hubert, M., Rings A. & Fürst, P. (2003). Influence of cooking process on phenolic marker compounds of vegetables. *International Journal of Vitamin and Nutrient Research*, 73 (2), 152-159.

Aoyama, S. & Yamamoto, Y. (2007). Antioxidant activity and flavonoid content of Welsh onion (Allium fistulosum) and the effect of thermal treatment. *Food Science and Technology Research*, 13(1), 67-72.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry*, 52(1), 1237-1241.

Ayranci, E. & Tunc, S. (2004). The effect of edible coatings on water and vitamin C loss of apricots (Armeniaca vulgaris Lam.) and green peppers (Capsicum annuum L.). *Food Chemistry*, 87(3), 339-342.

Azevedo-Meleiro, C.H. and Rodriguez-Amaya, D.B. (2005). Carotenoids of endive and New Zealand spinach as affected by maturity, season and minimal processing. *Journal of Food Composition and Analysis*, 18, 845-855.

Bahçeci, K.S., Serpen, A., Gökmen, V. & Acar, J. (2005). Study of lipoxygenase and peroxidase as indicator enzymes in green beans: change of enzyme activity, ascorbic acid and chlorophylls during frozen storage. *Journal of Food Engineering*, 66, 187-192.

Benkeblia, N. & Shiomi, N. (2004). Chilling effect on soluble sugars, respiration rate, total phenolics, peroxidase activity and dormancy of onion bulbs. *Science Agricola*, 61 (3), 281-285.

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Benkeblia, N., Ueno, K., Onodera, S. & Shiomi, N. (2005). Variation of fructooligosaccharides and their metabolizing enzymes in onion bulb (*Allum cepa* L. cv Tenshin) during long-term storage. *Journal of food science*, 70 (3), S208-S214.

Bernhardt, S. & Schlich, E. (2006). Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables. *Journal of Food Engineering*, 77, 327-333.

Bergquist, S.A.M., Gertsson, U.E., Knuthsen, P. and Olsson, M.E. (2005). Flavonoids in baby spinach (*Spinacia oleracea L.*): Changes during plant growth and storage. *Journal of Agricultural and Food Chemistry*, 53, 9459-9464.

Bergquist, S.A., Gertsson, U.E. and Olsson, M.E. (2006). Influence of growth stage and postharvest storage on ascorbic acid and carotenoid content and visual quality of baby spinach (*Spinacia oleracea* L.). Journal of the Science of Food and Agriculture, 86, 346-355.

Brewer, M.S. & Begum, S. (2003). Effect of microwave power level and time on ascorbic acid content, peroxidase activity and color of selected vegetables. *Journal of Food Processing Preservation*, 27, 411-426.

Canet, W., Alvarez, D.M., Luna, P. & Fernandez, C. (2004). Reprocessing effect on the quality of domestically cooked (boiled/stir-fried) frozen vegetables. *European Food Research and Technology*, 219, 240-250.

Canet, W., Alvarez, D.M., Luna, P., Fernandez, C. & Tortosa, M.E. (2005). Blanching effects on chemistry, quality and structure of green beans (cv. *Moncayo*). *European Food Research and Technology*, 220, 421-430.

Costa, M.L., Civello, P.M., Chaves, A.R. & Martinez, G.A. (2005). Effect of hot air treatments on senescence and quality parameters of harvested broccoli (Brasica oleracea L var Italica) heads. *Journal of the Science of Food and Agriculture*, 85, 1154-1160.

Costa, L., Vicente, A.R., Civello, P.M., Chaves, A.R. & Martinez, G.A. (2006). UV-C treatment delays postharvest senescence n broccoli florets. *Postharvest Biology and Technology,* 39, 204-210.

Czarniecka-Skubina, E. (2002). Effect of the material form, storage and cooking methods on the quality of Brussels sprouts. *Polish Journal of Food and Nutrition Sciences*, 11/52(3), 75–82.

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Del Pozo-Insfran, D.; Saldivar, S.O.S.; Brenes, C.H.; Talcott, S.T. (2007). Polyphenolics and Antioxidant Capacity of White and Blue Corns Processed into Tortillas and Chips, *Cereal Chemistry*, 84, 162–168.

de Oliveira G.P.R. & Rodriguez-Amaya D.B. (2007). Processed and prepared corn products as sources of lutein and zeaxanthin: Compositional variation in the food chain. *Journal of Food Science*, 72(1), S79+.

Dewanto, V., Wu, X. & Liu, R.H. (2002). Processed sweet corn has higher antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 50, 4959-4964.

Dutta, D., Raychaudhuri, Chakraborty, R. (2005). Retention of β-carotene in frozen carrots under varying conditions of temperature and time of storage. *African Journal of Biotechnology*, 4 (1), 102-108.

Garotte, R.L., Silva, E.R., Bertone, R.A. & Roa, R.D. (2006). Changes of ascorbic acid and surface color of green peas sterilized in cans subjected to end-over-end agitation. *Journal of Food Engineering*, 73, 29-37.

Gayathri, G.N., Platel, K., Prakash, J. & Srinivasan, K. (2004). Influence of antioxidant spices on the retention of β-carotene in vegetables during domestic cooking processes. *Food Chemistry*, 84, 35-43.

Gebzynski, P. & Lisiewska, Z. (2006). Comparison of the level of selected antioxidative compounds in frozen broccoli produced using traditional and modified methods. *Innovative Food Science and Emerging Technologies*, 7, 239-245.

Gebzynski, P. & Kmiecik, W. (2007). Effects of traditional and modified technology, in the production of frozen cauliflower, on the contents of selected antioxidative compounds. *Food Chemistry*, 101, 229-235.

Gennaro, L., Leonardi, C., Esposito, F., Salucci, M., Maiani, G, Quagliaz, G. & Fogliano, V. (2002). Flavonoid and carbohydrate contents in Tropea red onions: effects of homelike peeling and storage. *Journal of Agricultural and Food Chemistry*, 50, 1904-1910.

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Gliszczyńska-świgło, A.; Ciska, E.; Pawlak-Lemańska, K.; Chmielewski, J.; Borkowski, T.; Tyrakowska, B. (2006). Changes in the content of health-promoting compounds and antioxidant activity of broccoli after domestic processing, Food Additives and Contaminants, 23: 1088–1098

Gökmen, V. , Bahçeci, K.S., Serpen, A., & Acar, J. (2005). Study of lipoxygenase and peroxidase as blanching indicator enzymes in peas: change of enzyme activity, ascorbic acid and chlorophylls during frozen storage. *Food Science and Technology*, 38, 903-908.

Hart, D.J. & Scott, J. (1995). Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. *Food Chemisfry 54,* 101-111.

Hodges, D.M., Munro, K.D., Forney, C.F. and Mcrae, K.B. (2006). Glucosinolate and free sugar content in cauliflower (Brassica oleracea var. Botrytis cv. Freemont) during controlled-atmosphere storage. *Postharvest Biology and Technology*, 40, 123-132.

Hunter, K.J. and Fletcher, J.M. (2002). The antioxidant activity and composition of fresh, frozen, jarred and canned vegetables. *Innovative Food Science and Emerging Technologies*, 3, 399-406.

Jiratanan, T. & Liu, R.H. (2004). Antioxidant activity of processed table beets (*Beta vulgaris var. conditiva*) and green beans *(Phaseolus vulgaris* L.). *Journal of Agricultural and Food Chemistry*, 52, 2659-2670.

Kala, A. & Prakash, J. (2006). The comparative evaluation of the nutrient composition and sensory attributes of four vegetables cooked by different methods. *International journal of Food Science and Technology*, 41, 163-171.

Kalt, W. (2005). Effects of production and processing factors on major fruit and vegetable antioxidants. *Journal of Food Science*, 70 (1), R11-R19.

Kmiecik, W.; Lisiewska, Z.; Korus, A. (2007). Retention of mineral constituents in frozen brassicas depending on the method of preliminary processing of the raw material and preparation of frozen products for consumption. *European Food Research and Technology*, 224, 573–579.

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Leskova, E., Kubikova, J., Kovacikova, E., Kosicka, M, Porubska, J. & Holcikova, K. (2006). Vitamin losses: Retention during heat treatment and continual changes expressed by mathematical models. *Journal of Food Composition and Analysis*, 19, 252-276.

Lin, S. & Brewer, M.S. (2005). Effects of blanching method on the quality characteristics of frozen peas. *Journal of Food Quality*, 28, 350-360.

Lin, C.H. & Chang, C.-Y. (2005). Textural change and antioxidant properties of broccoli under different cooking treatments. *Food Chemistry*, 90, 9-15.

Lombard, K., Peffley, E., Geoffriau, E., Thompson, L. & Herring, A. (2005). Quercetin in onion (*Allium cepa* L.) after heat-treatment simulating home preparation. *Journal of Food Composition and Analysis*, 18, 571-581.

Masrizal, M.A., Giraud, D.W. & Driskell JA. (1997). Retention of vitamin C, iron and beta-carotene in vegetables prepared using different cooking methods. *Journal of Food Quality*, 20 (5), 403-418.

Mayer-Miebach, E., Behsnilian, D., Regier, M. & Schuchmann, H.P. (2005). Thermal processing of carrots: lycopene stability and isomerisation with regard to antioxidant potential. *Food Research International*, 38, 1103-1108.

McKillop, D.J., Pentieva K., Daly D., McPartlin J.M., Hughes J., Strain J.J., Scott J.M. & McNulty, H. (2002). The effect of different cooking methods on folate retention in various foods that are amongst the major contributors to folate intake in the UK diet. *British Journal of Nutrtion*, 88 (6), 681-688.

McNaughton, S.A. & Marks, G.C. (2003). Development of a food composition database for the estimation of dietary intakes of glucosinolates, the biologically active constitutents of cruciferous vegetables. *British Journal of Nutrition*, 90, 687-697.

Melse-Boonstra, A., Verhoef, P., Konings, E.J.M., Van Dusseldorp, M., Matser, A., Hollman, P.C.H., Meyboom, S., Kok, F.J. & West, C.E. (2002). Influence of processing on total, monoglutamate and polyglutamate folate contents of leeks, cauliflower, and green beans. *Journal of Agricultural and Food Chemistry*, 50, 3473-3478.

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Moreno, D.A.; L'opez-Berenguer, C.; Garcı̈a-Viguera, C. (2007). Effects of stir-fry cooking with different edible oils on the phytochemical composition of broccoli. *Journal of food science*, 72, S64-S68.

Ninfali, P. & Bacchiocca, M. (2003). Polyphenols and antioxidant capacity of vegetables under fresh and frozen conditions. *Journal of Agricultural and food chemistry*, 51, 2222-2226.

Nisha, P., Rekha, S.S., and Aniruddha, B.P., (2005). A study on degradation kinetics of riboflavin in spinach (*Spinacea oleracea L.*). *Journal of Food Engineering*, 67, 407-412.

Nunn, M.D.; Giraud, D.W.; Parkhurst, A.M.; Hamouz, F.L.; Driskell, J.A. (2006). Effects of cooking methods on sensory qualities and carotenoid retention in selected vegetables, *Journal of Food Quality*, 29, 445–457.

Nursal, B. & Yucecan, S. (2000). Vitamin losses in some frozen vegetables due to various cooking methods. *Nahrung-Food*, 44 (6), 451-453.

Oerlemans, K., Barrett, D.M., Bosch Suades, C., Verkerk, R. & Dekker, M. (2006). Thermal degradation of glucosinolates in red cabbage. *Food Chemistry*, 95, 19-29.

Pandrangi, S. and Laborde, L.F. (2004). Retention of folate, carotenoids, and other quality characteristics in commercially packaged fresh spinach. *Journal of Food Science*, 69, 702-707.

Punna, R. & Paruchuri, U.R. (2004). Effect of maturity and processing on tatal, insoluble and soluble dietary fiber contents of Indian green leafy vegetables. *International Journal of Food Sciences and Nutrition*, 55 (7), 561-567.

Ramesh, M.N., Wolf, W., Tevini, D. & Bognar, A. (2002). Microwave blanching of vegetables. *Journal of Food Science*, 67 (1), 390-398.

Rangkadilok, N., Tomkins, B., Nicolas,M.E., Premier, R.R., Bennett, R.N., Eagling, D.R. & Taylor, P.W.J. (2002). The effect of post-harvest and packaging treatments on glucoraphanin concentration in broccoli (Brassica oleracea var. italica). *Journal of Agricultural and Food Chemistry*, 50, 7386-7391.

Rehman, Z.U., Islam, M. & Shah, W.H. (2003). Effect of microwave and conventional cooking on insoluble dietary fibre components of vegetables. *Food Chemistry*, 80, 237-240.

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Serrano, M., Martinez-Romero, D., Guillen, F., Castillo, S. And Valero, D. (2006). Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging. *Postharvest Biology and Technology*, 39, 61-68.

Song, L. & Thornalley, P.J. (2007). Effect of storage, processing and cooking on glucosinolate content of Brassica vegetables, *Food and Chemical Toxicology* 45, 216–224.

Starzynska, A., Leja, M. & Mareczek, A. (2003). Physiological changes in the antioxidant system of broccoli flower buds senescing during short-term storage, related to temperature and packaging. *Plant Science*, 165, 1387-1395.

Turkmen, N, Sari, F., Velioglu, Y.S. (2005). The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. *Food Chemistry*, 93, 713-718.

Stea, T.H.; Johansson, M.; Jägerstad, M.; Frølich, W. (2006). Retention of folates in cooked, stored and reheated peas, broccoli and potatoes for use in modern large-scale service systems. *Food Chemistry*, 101, 1095–1107.

Vallejo, F., Tomas-Barberan, F.A. and Garcia-Viguera, C. (2002). Glucosinolates and vitamin C content in edible parts of broccoli florets after domestic cooking. *European Food Research and technology*, 215, 310-316.

Vallejo, F., Tomas-Barberan, F. and Garcia-Viguera, C. (2003a). Health-promoting compounds in broccoli as influences by refrigerated transport and retail sale period. *Journal of Agricultural and Food Chemistry*, 51, 3029-3034.

Vallejo, F., Tomas-Barberan, F.A. and Garcia-Viguera, C. (2003b). Phenolic compound contents in edible parts of broccoli inflorescences after domestic cooking. *Journal of the Science of Food and Agriculture*, 83, 1511-1516.

Viňa, S.Z.; Mugridge, A.;Garcı´a, A.; Ferreyra, R.M.; Martino, M.N.; Chaves, A.R.; Zaritzky, N.E. (2007). Effects of polyvinylchloride films and edible starch coatings on quality aspects of refrigerated Brussels sprouts, *Food Chemistry* 103, 701–709.

Viňa, S.Z.; Olivera, D.F.; Marani, C.M.; Ferreyra R.M.; Mugridge, A.; Chaves, A.R.; Mascheroni, R.H. (2007) Quality of Brussels sprouts (Brassica oleracea L. gemmifera DC) as affected by blanching method. *Journal of Food Engineering* 80, 218–225.

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Wennberg, M., Engqvist, G. & Nyman, M. (2002). Effects of harvest time and storage on dietary fibre components in various cultivars of white cabbage (Brassica oleracea var capitata). *Journal of the Science of Food and Agriculture*, 82 (12), 1405-1411.

Winkler, S.; Faragher, J.; Franz, P.; Imsic, M.; Jones, R. (2007). Glucoraphanin and flavonoid levels remain stable during simulated transport and marketing of broccoli (Brassica oleracea var. italica) heads. Postharvest Biology and Technology, 43, 89–94

Yamaguchi, T., Katsuda, M., Oda, Y., Terao, J., Kanazawa, K., Oshima, S., Inakuma, T., Ishiguro, Y., Takamura, H. and Matoba, T. (2003). Influence of polyphenol and ascorbate oxidases during cooking process on the radical-scavenging activity of vegetables. *Food Science and Technology Research*, 9, 79-83.

Zhang, D. And Hamauzu, Y. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chemistry*, 88, 503-509.

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4. SUMMARIES VEGETABLES

Agostini, L.R., Jimenez, M.J.M., Ramon, A.N. & Gomez, A.A. (2004). Determinacion de la capacidad antioxidante de flavonoides en frutas y verduras frescas y tratadas termicamente. *Archivos Latinoamericanos de Nutricion*, 54, 89-92.

The main objective of the work was to determine the antioxidant capacity of the flavonoids in apples, strawberries and onions, fresh compared with thermally treated: boiling (6-23 min), steam cooking (3-22 min), dry heat (9-31min) and microwave (1,3-2,5 min).

For apples with skin antioxidant capacity, measured as µM Trolox Equivalent, retention was: 91,5, 86,1, 66,4 and 49,4% for boiling, steam cooking, microwaving and drying respectively.

For strawberries antioxidant capacity, measured as µM Trolox Equivalent, retention was: 81,3, 82,0, 49,6 and 27,7% for boiling, steam cooking, microwaving and drying respectively.

For onions antioxidant capacity, measured as µM Trolox Equivalent, retention was: 65,5, 67,7, 88,8 and 70,9% for boiling, steam cooking, microwaving and drying respectively.

Amin, I., Zamaliah, M.M. & Chin, W.F. (2004). Total antioxidant activity and phenolic content in selected vegetables. *Food chemistry*, 87, 581-586.

The purpose of this study was to determine the total antioxidant activity and phenolic content of fresh and thermally treated vegetables.

Five types of vegetables were selected namely kale, spinach, cabbage, shallot and swamp cabbage. The vegetables were cleaned and washed. 300 g edible portions of the vegetables were boiled for 1 min in 500 ml water and then air-dried under a fan. 100 g of sample was cut and homogenized then transferred into an air-tight container and kept at -20 ^{o}C before the extraction.

From the result, the antioxidant activity of fresh and thermally treated vegetables was presented in a descending order. The antioxidant activity of fresh spinach was 66.4 %, with was a little bit higher as the value for cabbage (59.3 %). The mean antioxidant activities of boiled vegetable were similar to the fresh vegetables.

The mean antioxidant activities of boiled vegetables were similar to the fresh vegetables. Cabbage lost 20 % and spinach lost 14 % of phenolic content after one minute blanching in boiling water.

Andlauer, W., Stumpf, C., Hubert, M., Rings A. & Fürst, P. (2003). Influence of cooking process on phenolic marker compounds of vegetables. *International Journal of Vitamin and Nutrient Research*, 73 (2), 152-159.

The aim of the present study was to asses the influence of different volumes of cooking water on the amount of selected phenolic marker compounds resting in the vegetables.

In fresh zucchini, rutin was quantified as a marker for flavonoid glycosides. Cooking zucchini with a low volume (30ml) of water resulted in a decrease of rutin content of 21,1%, while cooking in a large volume (300ml) of water decreased the rutin content with 30,6%.

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Chlorogenic acid, representative of phenolic acids was analyzed in fresh carrots. Cooking carrots with a low volume (30ml) of water resulted in a decrease of chlorogenic acid content of 25,4%, while cooking in a large volume (300ml) of water decreased the chlorogenic acid content with 62,8%.
In frozen green beans, rutin and quercitrin, both belonging to flavonoid glycosides, were investigated. Cooking green beans with a low volume (40ml) of water resulted in a decrease of rutin content of 1,8%, while cooking in a large volume (300ml) of water decreased the rutin content with 29,7%. Cooking green beans with a low volume (40ml) of water resulted in a decrease of quercitrin content of 0,9%, while cooking in a large volume (300ml) of water decreased the quercitrin content with 26,7%.
The cooking of zucchini, carrots and green beans with smaller amounts of water results in significant higher content of phenolic phytochemicals in these vegetables compared to cooking with larger water volumes.

Aoyama, S. & Yamamoto, Y. (2007). Antioxidant activity and flavonoid content of Welsh onion (Allium fistulosum) and the effect of thermal treatment. *Food Science and Technology Research*, 13(1), 67-72.

Antioxidant activity and flavonoid content of Welsh onion (Allium fistulosum) (green-leafy and white sheet varieties) and the effect of thermal treatment on them were studied by comparing with those of onion (Allium cepa) (yellow and red varieties). Antioxidant activity was measured by Trolox equivalent antioxidant capacity (TEAC) and ferric reducing antioxidant power (FRAP) assays. The order of these indices of antioxidant activity was red onion > yellow onion = green Welsh onion >> white Welsh onion. Major flavonoid of yellow and red onions was quercitin, and that of green Welsh onion was kaempferol. Antioxidant activity of green Welsh onion was increased, but that of the other three vegetables was decreased during boiling for more than 15 minutes. Flavonoids in green Welsh onion Were less stable than those in the other three vegetables during the boiling procedure. These results suggested that green Welsh onion, but not the white one, is a potent antioxidant food comparable to yellow onion, and is a good source of kaempferol. Increased antioxidant activity and decreased flavonoid content during boiling were characteristics of green Welsh onion.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry*, 52(1), 1237-1241.

No significant differences in total phenolics were observed between frozen and freeze-dried corn. Air-drying however resulted in a 30% decrease in total phenolics level, compared to frozen and freeze-dried samples.

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Ayranci, E. & Tunc, S. (2004). The effect of edible coatings on water and vitamin C loss of apricots (Armeniaca vulgaris Lam.) and green peppers (Capsicum annuum L.). *Food Chemistry*, 87(3), 339-342.

Edible coatings of varying composition were applied on green peppers. The vitamin C content was compared with those of non-coated products. Coated and uncoated products were kept at 25°C and 84% relative humidity. After 12 days of storage the non-coated green peppers showed a 72% decrease in vitamin C while for the coated green peppers this loss varied between 70 and 51%.

Azevedo-Meleiro, C.H. and Rodriguez-Amaya, D.B. (2005). Carotenoids of endive and New Zealand spinach as affected by maturity, season and minimal processing. *Journal of Food Composition and Analysis*, 18, 845-855.

Not being subjected to thermal and other drastic processing conditions, minally processed products are expected to retain fresh or fresh-like properties and nutritive quality. The carotenoid contents of marketed minimally processed endive and New Zealand spinach were determined during 5 days of storage at 7-9 °C. β-carotene, lutein, violaxanthin, and neoxanthin were reduced 18 %, 19 %, 12 % and 8 %, respectively, in minimally processed endive. The corresponding losses in New Zealand spinach were 42 %, 32 %, 20 % and 20 %.

It must be mentioned that the losses observed in this study occurred under unoptimized packaging and storage conditions. Retention of the carotenoids could be improved, for example, by using modified atmosphere packaging and lower storage temperature.

Bahçeci, K.S., Serpen, A., Gökmen, V. & Acar, J. (2005). Study of lipoxygenase and peroxidase as indicator enzymes in green beans: change of enzyme activity, ascorbic acid and chlorophylls during frozen storage. *Journal of Food Engineering*, 66, 187-192.

The objective of this study was to optimize blanching operations for green beans in terms of enzyme reactivation and losses of ascorbic acid and chlorophylls during frozen storage using LOX and POD enzymes as blanching indicators, separately.

The initial AA (ascorbic acid) content of unblanched fresh beans was found to be 222,42 mg/kg and it decreased to 153,60 mg/kg (30,9% decrease) after blanching at 70°C for 2 min and 133,34 mg/kg (40,1% decrease) after blanching at 90°C for 3 min, respectively. AA content of unblanched green beans decreased significantly during frozen storage following .first order kinetics. AA losses in unblanched, 70°C, 2,0 min blanched and 90°C, 3,0 min blanched green beans were found to be 93,65%, 86,21% and 68,64% after 6 months of storage, respectively. During frozen storage of unblanched green beans at -18°C, the half-life of AA was calculated as 1,89 months. It increased to 2,15 and 3,48 months by blanching at 70°C for 2 min and 90°C for 3 min, respectively.

The first step of AA degradation is oxidation to DHAA (dehydroascorbic acid) and in the second step, it hydrolyses to diketogluconic acid. While AA and DHAA have equal antiscorbutic activity,

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diketogluconic acid has no biological activity. So AA together with DHAA constitute of total vitamin C effect. Unblanched green beans were found to contain 25,69 mg/kg of DHAA prior to frozen torage. DHAA content of unblanched green beans tended to increase for 3 months then to decrease through storage.

Blanching treatments prior to frozen storage resulted in an increase on DHAA contents of green beans as a results of AA oxidation. Similar to AA, DHAA contents of blanched green beans also tended to decrease through frozen storage. Only green beans in which blanched at 90°C for 3 min to inactivate POD contained AA and DHAA while unblanched and blanched at 70°C for 2 min green beans contained any AA and DHAA at the end of 9 months of frozen storage.

Overall results suggests using POD as the indicator of blanching adequacy in green beans to be frozen.

Benkeblia, N. & Shiomi, N. (2004). Chilling effect on soluble sugars, respiration rate, total phenolics, peroxidase activity and dormancy of onion bulbs. *Science Agricola*, 61 (3), 281-285.

This study aimed to investigate the effects of low temperature (0 ^{o}C) on the dormancy break of onion bulbs and biochemical changes in inner bud sprouts. Onion bulbs cv. Rouge Amposta, freshly harvested and dried in the field for two weeks, packed in commercial 12 kg plastic (PVC) trays and placed at 18 ^{o}C prior to the cooling at 0 ^{o}C in the dark during four weeks and then transferred in dark to the 20 ^{o}C and 65% relative humidity condition. Comparatively to of freshly harvested bulbs, total phenolics in the inner bud of cold-treated bulbs increased to 0.2 mg g^{-1} fresh weight during first two weeks. Then, decreased abruptly to 0.13 mg after four weeks and progressively to 0.11 mg/g during the next four weeks. On the other hand, for control samples, TP content was rather regular showing a slight increase from 0.17 to 0.2 mg/g FW during five weeks and then decreased progressively to 0.15 mg/g during the last three weeks. Their role in the bulb dormancy is unclear but phenolic compounds seem to inhibit sprouting and low temperature may trigger a signal which could be responsible for the decrease of these compounds, promoting sprout initiation and development. Cold treatment at 0 °C could contribute to induce breakage of dormancy of onion bulbs. These low temperatures also cause a decrease in total phenolics and peroxidase activity.

Benkeblia, N., Ueno, K., Onodera, S. & Shiomi, N. (2005). Variation of fructooligosaccharides and their metabolizing enzymes in onion bulb (*Allum cepa* L. cv Tenshin) during long-term storage. *Journal of food science*, 70 (3), S208-S214.

The objective of this study was to assess the status of fructooligosaccharides (FOS) in onion bulbs during storage at 15°C. Onion bulbs, *Allium cepa* cv Tenshin (summer cultivar), were freshly harvested and cured in the field. The bulbs were sorted for uniformity and absence of defects and packed in commercial polyvinyl chloride (PVC) plastic trays of 12 kg each and than stored.

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The FOS were extracted by the method of Shiomi and analyzed by high-performance anion exchange chromatography and a pulsed amperometric detector.

Lower degree of polymerization (DP 3 to 6) FOS, higher (DP 7 to 12) FOS, total FOS and total carbohydrates showed similar and close patterns during 24 weeks. They varied slightly at the beginning of the storage period, afterward they decreased progressively and regularly during the last 20th week of storage.

Lower FOS (DP 3 to 6) of onion bulbs showed close patterns during 24 weeks. After a steady state (DP3 and 4) or an increase (DP 5 and 6) observed between week 2 and week 6, lower FOS decreased progressively during 18th week and were 3.12, 1.57, 0.96 and 0.59 mg/m fresh weight (FW) for DP 3, 4, 5, and 6 respectively. The average decrease rates of these FOS from week 6 and week 24 were 220, 270, 3000 and 1600 μg/g FW/ wk for DP 3, 4, 5 and 6 respectively.

Higher DP FOS showed similar pattern. FOS of DP 7 and 8 increased slightly during the 1st 2 weeks, from 1.13 and 0.75 mg/g to 1.52 and 0.93 mg/g FW respectively, and then decreased progressively and regularly to 0.22 and 0.13 mg/g FW, respectively during the last 18 weeks. On the other hand, FOS of about DP 12 decreased linearly from 1.38 to 0.24 mg/g FW during 24 weeks. The average decrease rates from week 6 and week 24 were 54, 33, and 38 μg/g FW per week for DP7, 8 and up to 12 respectively.

After a steady state observed during the 1st 6 weeks, total FOS decreased progressively from 26.12 to 6.82 mg/g FW during the 18th week and their average decrease rate from week 6 and week 24 was 1,072 μg/g FW/weak.

Thus and with regard to the average decrease rates of the different FOS, it can be noted that this rate increased with the increasing of the degree of polymerisation.

Bernhardt, S. & Schlich, E. (2006). Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables. *Journal of Food Engineering*, 77, 327-333.

The bioavailability of all-trans-b-carotene from vegetables depends among other things on the molecular linkage and the food matrix in which it is incorporated. It is assumed that cooking can increase the bioavailability by disruption of the plant cell wall and releasing from protein complexes. But it can also lead to isomerization and degradation of all-trans-b-carotene. In this investigation the influence of different domestic cooking methods on the all-trans- and cis-b-carotene as well as the a-tocopherol content in fresh and frozen broccoli and red sweet pepper is examined. While in fresh broccoli all cooking methods lead to a significant release of all-trans-b-carotene and a-tocopherol in the frozen broccoli no change or a decrement occurs. In the fresh and frozen peppers no change or a significant loss of a-tocopherol and all-trans-b-carotene is observed. A slight increase in the cis-isomers of b-carotene can only be found by cooking fresh broccoli.

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Bergquist, S.A.M., Gertsson, U.E., Knuthsen, P. and Olsson, M.E. (2005). Flavonoids in baby spinach (*Spinacia oleracea L.*): Changes during plant growth and storage. *Journal of Agricultural and Food Chemistry*, 53, 9459-9464.

The aim of this research was to investigate the quantitative and qualitative variation in flavonoids with sowing time and growth stage of baby spinach. In addition, the postharvest stability of baby spinach flavonoids was studied during 9 days of storage at different temperatures. After harvest, leaves were stored in polypropylene bags at 2 or 10 °C. Each bag contained approximately 100 g and was stored for 5 and 9 days in a climate chamber at 10 or 2 °C simulating practical commercial conditions.

Previous research on flavonoids in spinach has identified rather rare flavonoid glycosides that are not commonly found in other vegetables.

Total flavonoid content was relatively stable during normal retail storage conditions, although some of the individual flavonoid compounds showed considerable variation.

Bergquist, S.A., Gertsson, U.E. and Olsson, M.E. (2006). Influence of growth stage and postharvest storage on ascorbic acid and carotenoid content and visual quality of baby spinach (*Spinacia oleracea* L.). Journal of the Science of Food and Agriculture, 86, 346-355.

Leafy vegetables have relatively low storage potential in terms of visual quality, as well as other quality parameters such as microbial growth and nutritional content. The variation in quality with growth stage and postharvest storage of baby spinach was investigated. After harvest, the leaves were stored in polypropylene bags at 2 °C or 10 °C. The retention of ascorbic acid after 9 days of storage at 10 °C as compared to at harvest was 0 % when the plants were sown under normal commercial conditions. For storage at 2 °C the retention was 25%. The carotenoid content was rised with 14 % after storage during 9 days at 10 °C. For storage at 2 °C the carotenoid content rised with 13 %.

By harvesting baby spinach a few days earlier than the current commercial stage of harvest visual quality and nutritional quality can be improved.

Brewer, M.S. & Begum, S. (2003). Effect of microwave power level and time on ascorbic acid content, peroxidase activity and color of selected vegetables. *Journal of Food Processing Preservation*, 27, 411-426.

The objective of this study was to evaluate the effects of treatment with various microwave power levels for various times on peroxidase inactivation and ascorbic acid (AA) and color preservation in broccoli, green beans and asparagus.

For broccoli, when adjusted for moisture loss, it is apparent that as treatment time increased, AA content decreased regardless of power level. Higher power levels (70% and 100%; 700W microwave) produced broccoli with less AA at all times than did lower power levels. Losses of

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ascorbic acid (adjusted for moisture loss) were situated between 5,7% and 66,8% for a treatment of 1 min at 30% power level and 4 min at 100% power level respectively.
Microwave heating had less affect on AA content of green beans than on broccoli. When adjusted for moisture loss, beans subjected to 100% and 70% power had less than half the original content AA (adjusted) than raw beans after 3 min and 4 min heating respectively. Adjusted AA content of samples heated at 30% and 55% power for 1 to 4 min was about the same as that of raw samples. Losses of ascorbic acid (adjusted for moisture loss) were situated between 0,0% and 65,1% for a treatment of 1 min at 30% power level and 4 min at 100% power level respectively.

Canet, W., Alvarez, D.M., Luna, P. & Fernandez, C. (2004). Reprocessing effect on the quality of domestically cooked (boiled/stir-fried) frozen vegetables. *European Food Research and Technology*, 219, 240-250.
The author states that the influence of the different final cooking methods on the texture, colour and nutrient retention of the frozen vegetables is largely unknown. One of the objects of the present research was to study and compare the effect of two commonly used domestic cooking methods (boiling and stir-frying) on different quality parameters of frozen green peas and beans.
In all the studied vegetables, less chlorophyll and more ascorbic acid were retained when samples were stir-fried then when they were boiled, although chlorophyll and ascorbic acid decreased with increasing reprocessing time (blanching at 97°C for 2, 4 or 8 min and freezing prior to stir-frying or boiling) in both cooking methods.

Canet, W., Alvarez, D.M., Luna, P., Fernandez, C. & Tortosa, M.E. (2005). Blanching effects on chemistry, quality and structure of green beans (cv. *Moncayo*). *European Food Research and Technology*, 220, 421-430.
Green beans (cv. *Moncayo*) were blanched at 65, 70, 75, 80, 85, 90 and 97°C for 2,5, 5, 10, 20 and 40 min. Pectinesterase activity was highest in cell-wall-bound extracts of beans blanched at 70°C/10min. The lowest water-soluble pectin fraction, the highest EDTA-soluble pectin fraction and the lowest degree of esterification of the EDTA-soluble fraction were all recorded for the same temperature/time combination; these effects can therefore be attributed to PE activity. Chemical changes did not affect initial firmness of the beans, which was practically constant after blanching at 65, 70, 75 and 80°C. Simple first-order models were adequate to establish softening kinetics for beans blanched at 85, 90 and 97°C. For all temperatures, short-time blanching increased the coloration and total chlorophyll content of the samples with respect to fresh control. In the treated beans the ascorbic acid content was consistently lower than in the control and decreased continuously with increasing time.

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Costa, M.L., Civello, P.M., Chaves, A.R. & Martinez, G.A. (2005). Effect of hot air treatments on senescence and quality parameters of harvested broccoli (Brasica oleracea L var Italica) heads. *Journal of the Science of Food and Agriculture*, 85, 1154-1160.

This work investigated the effect of a hot air treatment (48°C for 3h, i.e. optimized to delay yellowing and chlorophyll degradation) on quality parameters (total antioxidant power) during the postharvest storage of broccoli florets.

The level of antioxidants decreased during storage at 20°C. In control samples the antioxidant capacity decreased from day 1 and this continued until day 4, reaching a decrement of almost 70%. In contrast, in heat treated samples the antioxidant capacity decreased from day 2 and was higher than that in the control until day 3. On day 4 the antioxidant capacity decreased and reached a value similar to that of the control.

Costa, L., Vicente, A.R., Civello, P.M., Chaves, A.R. & Martinez, G.A. (2006). UV-C treatment delays postharvest senescence n broccoli florets. *Postharvest Biology and Technology,* 39, 204-210.

Broccoli was stored at 20°C for 5 days in the dark. The antioxidant capacity maintained during storage until day 4 and decreased thereafter (to 65% of the original value after 6 days). Total phenols increased during storage (doubled over 6 days storage). Flavonoids also increased during storage (doubled after 4 days storage).

Czarniecka-Skubina, E. (2002). Effect of the material form, storage and cooking methods on the quality of Brussels sprouts. *Polish Journal of Food and Nutrition Sciences*, 11/52(3), 75–82.

Retention of vitamin C in Brussels sprouts strongly depends on the cooking method. High retention of this vitamin was found for cooking in a microwave oven, pressure cooker in steam and acuthermal pot, losses of vitamin C were from 3.7% to 10.6%. On the contrary, low retention of vitamin C was noted for traditional cooking in a pot starting with cold water (loss 38.6%), in pressure cooker starting with boiling water (31.3%), and in a pot starting with boiling water (27.6%).After blanching and canning of Brussels sprouts, a decrease of vitamin C by 66% was observed, that was about 2-fold higher than in case of blanching (4.5 min at 93–95 1C) and freezing (loss 34%)

Del Pozo-Insfran, D.; Saldivar, S.O.S.; Brenes, C.H.; Talcott, S.T. (2007). Polyphenolics and Antioxidant Capacity of White and Blue Corns Processed into Tortillas and Chips, *Cereal Chemistry*, 84, 162–168.

White and blue corns of Mexican and American origins were limecooked to obtain nixtamals with optimal moisture (48–50%) for tortillas and chips. Blue kernels had less bulk density, softer endosperm and, consequently, required less cooking time than the white kernels. The optimum

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cooking regime for the white kernels was 100°C for 20 min, while the optimum for both pigmented genotypes was 90°C for 0 min (until the lime-cooking solution reached 90°C). Doughs, tortillas, and chips were characterized by total soluble phenolics (TSP), anthocyanins (ACN), and antioxidant capacity (AOX). A dough acidification procedure using fumaric acid (pH 5.2) was assessed as a means to improve TSP, ACN, and AOX retention. The Mexican blue corn had higher AOX (16%) than the American blue genotype, although the latter had a threefold higher TSP content (12.1 g/kg, dwb). Mexican and American blue corns had higher AOX capacity (29.6 and 25.6 μM trolox equivalents [TE]/g dwb), respectively, than the white corn (17.4 μM TE/g). White corns did not have detectable amounts of ACN, while blue Mexican and American kernels contained 342 and 261 mg/kg. Lime cooking had the greatest negative impact on the stability of TSP, ACN, and AOX. However, the acidification reduced ACN, TSP, and AOX losses by 8–23, 3–14, and 4–15%, respectively. Similar ACN losses were observed for both types of blue kernels when processed into nixtamal/dough (47%); however, ACN losses in tortillas and chips manufactured from the American blue genotype were higher (63 and 81%, respectively) than those of Mexican blue corn products (54 and 75%). ACN losses were highly correlated to TSP (r = 0.91) and AOX capacity losses (r = 0.94).

de Oliveira G.P.R. & Rodriguez-Amaya D.B. (2007). Processed and prepared corn products as sources of lutein and zeaxanthin: Compositional variation in the food chain. *Journal of Food Science*, 72(1), S79+.

Widely consumed by populations of all socioeconomic classes worldwide, **corn** is one of the few food sources of lutein and zeaxanthin. However, data on these **carotenoids** in processed **corn** and **corn** as eaten are lacking. Thus, the major **carotenoids** in the principal brands of processed **corn** (canned **corn**, **corn** meal, **corn** flour, **corn** flake) and in typical **corn** dishes (farofa, boiled **corn**, pamonha, curau, fried and boiled polenta) were determined. There was marked variation between processed products and between brands of the same product, but variation between lots of the same brand was small. Canned **corn** had the highest zeaxanthin (11.91 to 18.06 mu g/g), beta-cryptoxanthin (2.32 to 3.77 mu g/g), and beta-**carotene** (1.79 to 2.75 mu g/g) contents. The **corn** flake breakfast cereal had the second highest amount of zeaxanthin (9.08 to 12.77 mu g/g). **Corn** meal had the highest lutein (4.02 to 7.62 mu g/g) level and also had good zeaxanthin content (6.13 to 11.39 mu g/g), but drastic reduction of all **carotenoids**, especially zeaxanthin, occurred when it was toasted to farofa. Boiled **corn** also had lower **carotenoid** levels compared to the raw **corn**. The wide variations in **carotenoid** concentrations appeared to be due mainly to varietal differences in the **carotenoid** composition of raw materials and to losses during processing and preparation for consumption.

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Dewanto, V., Wu, X. & Liu, R.H. (2002). Processed sweet corn has higher antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 50, 4959-4964.

The objective of this study was to evaluate the effect of thermal processing on the antioxidant activity of sweet corn by assessing contents of total phenolics and vitamin C of raw and thermally processed sweet corn.

A homogeneous sample of corn kernels was packed in cans. The cans were subjected to six different treatments: raw, cooked at 115°C for 10, 25 or 50 min and cooked at 100, 115 and 121°C for 25 min.

Vitamin C content declined with increasing heating time at 115°C with a reduction of 16,7, 25,0 and 45,8% for 10, 25 and 50 min respectively. After heating at 100, 115 and 121°C for 25 min the vitamin C content dropped with 8,3, 25,0 and 41,7% respectively compared with raw unprocessed sweet corn.

Total free phenolic content increased with increasing heating time at 115°C with an increase of 24,0, 32,0 and 36,0% for 10, 25 and min respectively. After heating at 100, 115 and 121°C for 25 min the total free phenolic content increased with 16,0, 32,0 and 48,0% respectively compared with raw unprocessed sweet corn. On other hand there was a decrease in bound phenolic content across both heating time and heating temperature.

Dutta, D., Raychaudhuri, Chakraborty, R. (2005). Retention of β-carotene in frozen carrots under varying conditions of temperature and time of storage. *African Journal of Biotechnology*, 4 (1), 102-108.

The objective was to determine the change in β-carotene content of carrots of Indian variety with regard to its blanching time and its retention when subjected to different temperatures and times of storage.

Heat treatment such as blanching, cooking and steaming help to release bound carotenoids and render them to be easily extractable and hence the β-carotene content has increased from 84,0 (fresh sample) to 100,8 µg/g (in 3 min blanched sample). Carrots blanched for 3 min have higher β-carotene content (100,8 µg /g) than those blanched for 5 min (88,6 µg/g).

As the storage period increases, there is a significant decrease in the β-carotene content of carrot. The β-carotene content decreases more drastically over the period of 80 days. The change in β-carotene content is insignificant compared to the initial value when the samples are stored at -18°C. There is a gradual decrease of the β-carotene content as the temperature is raised from -18°C to 0°C, the loss being more significant at 0°C. The decrease is about 40,2% for 3 min blanching time and about 31,5% for 5 min blanching time for a storage period of 80 days at 0°C, whereas for -18°C it is 1,2% for 3 min blanch time and 6,5% for 5 min blanch time.

In conclusion, β-carotene content does decrease when kept for a storage period of 80 days but the decrease is more evident at 0°C than at lower temperatures. 3 min blanch treatment is a better way

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of retaining β-carotene than 5 min blanch treatment. Low temperature freezing retains most of the β-carotene in carrots and retention is highest at -18°C for both 3 min and 5 min blanching times.

Garotte, R.L., Silva, E.R., Bertone, R.A. & Roa, R.D. (2006). Changes of ascorbic acid and surface color of green peas sterilized in cans subjected to end-over-end agitation. *Journal of Food Engineering*, 73, 29-37.

The objective of this work was to study the changes of ascorbic acid and surface color during the end-over-end thermal sterilization of canned green peas, as a function of retort temperature (110, 120 or 130°C), agitation speed (5, 10, 15 rpm), and headspace (4, 8, 12 mm in cans with inner diameter = 69.8 mm and height = 107 mm), using the response surface methodology. Changes of ascorbic acid retained by green peas, ascorbic acid leached to brine and ascorbic acid lost were reported.

Responses fluctuated between wide limits. AA retained by green peas ranged between 43% and 79%, AA leached to brine fluctuated between 4% and 25%, while AA lost varied between 10% and 33%. It is seen that at higher retort temperatures–shorter processing times AA retained by green peas is increased. From response surface models developed for ascorbic acid the most appropriate processing conditions are T = 130°C, agitation = 5 rpm, headspace = 12 mm, for which AA retained by green peas, AA leached to brine and AA lost are 80,3%, 14,7%, and 5,0% respectively.

Gayathri, G.N., Platel, K., Prakash, J. & Srinivasan, K. (2004). Influence of antioxidant spices on the retention of β-carotene in vegetables during domestic cooking processes. *Food Chemistry*, 84, 35-43.

This study was conducted to determine the extent of retention of β-carotene in representative vegetables, which are rich sources of the same during conventional cooking procedures. This study also examined the influence of commonly used acidulants and of spices known to have antioxidant properties on the extent of retention of β-carotene.

Pressure cooking and boiling for 10 min of fresh carrots resulted in a β-carotene retention of 73% and 84% respectively. Pressure cooking and boiling for 10 min of fresh carrots in the presence of several acidulants and spices resulted in a β-carotene retention of 73-96% and 80-97% respectively.

Gebzynski, P. & Lisiewska, Z. (2006). Comparison of the level of selected antioxidative compounds in frozen broccoli produced using traditional and modified methods. *Innovative Food Science and Emerging Technologies*, 7, 239-245.

The investigation concerned frozen broccoli produced using a traditional method, i.e. from the raw material blanched before freezing, and a modified method of freezing cooked broccoli. In comparison with blanched broccoli the material cooked before freezing contained more dry

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matter, carotenoids and beta-carotene and less vitamin C and polyphenols; its antioxidative activity was also poorer. In frozen products stored for 0, 4, 8 and 12 months at −20 or −30 °C and then cooked, a steady decrease was observed in the content of all the constituents. Compared with the raw material cooked broccoli stored for 12 months contained 29–33% of vitamin C, 54–66% of polyphenols, 80–97% of carotenoids, 69–80% of beta-carotene and showed a 29–35% decrease in the antioxidative activity. A higher or similar level of the above properties was found in samples cooked before freezing as compared with blanched goods; a higher level was ascertained in samples stored at −30 °C compared with those stored at −20 °C. The same sensory quality was found for frozen goods obtained with both methods. Frozen products and ready-to-eat frozen products stored at −30 °C had higher sensory quality.

Gebzynski, P. & Kmiecik, W. (2007). Effects of traditional and modified technology, in the production of frozen cauliflower, on the contents of selected antioxidative compounds. *Food Chemistry*, 101, 229-235.

The investigation concerned white and green cauliflowers: a traditional technology of freeze – blanched cauliflower, a modified technology of freeze – cooked cauliflower, and two temperatures of frozen storage at _20 and _30 _C for 0, 4, 8, and 12 months. Compared with the white cauliflower, the green variety was characterized by significantly greater contents of dry matter, vitamin C, carotenoids, bcarotene, polyphenols and a higher antioxidative activity at all the stages of evaluation. Depending on the investigated sample, after 12 months of refrigerated storage, cauliflower prepared for consumption retained 29–50% of vitamin C, 73–100% of carotenoids, 53–125% of b-carotene, 69–85% of polyphenols and 26–40% of antioxidative activity in comparison with the raw material. After a 12-month storage, the product obtained using the modified technology contained significantly more vitamin C and in general showed a higher antioxidative activity than did with the traditional product. The lower storage temperature resulted in significantly better retention of vitamin C and also – in some samples – a better retention of carotenoids, b-carotene, and polyphenols. A higher sensory quality was found in products of green cauliflower obtained according to the traditional technology.

Gennaro, L., Leonardi, C., Esposito, F., Salucci, M., Maiani, G, Quagliaz, G. & Fogliano, V. (2002). Flavonoid and carbohydrate contents in Tropea red onions: effects of homelike peeling and storage. *Journal of Agricultural and Food Chemistry*, 50, 1904-1910.

Because onion peeling for consumption results in some nutritional compounds being lost with the external layers, the main flavonoids and carbohydrates present in three parts of the bulb were quantified.

The anthocyanins are heavily concentrated in the skin and in the outer fleshy layer, whereas in the edible tissue they are restricted to a single layer of cells in the epidermal tissue. After bulb peeling only 27 % of the total anthocyanins of the red onion are retained.

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For quercitin this figure is different: 79% of the total amount of this compound is still present in the edible portion after peeling.

In a second experiment the bulbs were analyzed in relation to three storage conditions: 5°C, RH 30%; 25°C, RH 66%; 30°C, RH 50%. After 6 weeks of storage in all conditions, the whole anthocyanin content is decreased between 64 and 73%. The same trend was observed for the total antioxidant activity. Trolox Equivalent antioxidant capacity was reduced by 29% after 6 weeks at 5°C and by 36% when bulbs were stored in warm ambient conditions.

In conclusion Tropea red onion is a rich source of quercitin. On the other hand anthocyanin intake will be limited because a significant portion of it is eliminated during peeling. Storage at low temperature and in low humidity conditions seems to better preserve the onion anthocyanins.

Gliszczyńska-świgło, A.; Ciska, E.; Pawlak-Lemańska, K.; Chmielewski, J.; Borkowski, T.; Tyrakowska, B. (2006). Changes in the content of health-promoting compounds and antioxidant activity of broccoli after domestic processing, Food Additives and Contaminants, 23: 1088–1098

The effect of water- and steam-cooking on the content of vitamin C, polyphenols, carotenoids, tocopherols and glucosinolates, as well as on the antioxidant activity of broccoli, are reported. Flavonoids, phenolic acids, vitamins C and E, β-carotene, lutein, and glucosinolates in domestically processed broccoli were quantified using high-performance liquid chromatography (HPLC) methods; total polyphenols were determined with Folin–Ciocalteu reagent. The antioxidant capacities of broccoli extracts were evaluated using the Trolox equivalent antioxidant capacity (TEAC) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) methods. The results indicated that steam-cooking of broccoli results in an increase in polyphenols, as well as the main glucosinolates and their total content as compared with fresh broccoli, whereas cooking in water has the opposite effect. Steam-cooking of broccoli has no influence on vitamin C, whereas cooking in water significantly lowers its content. Both, water- and steam-cooking of broccoli results in an increase in β -carotene, lutein, and α- and γ-tocopherols as compared with fresh broccoli. Similar effects of steaming and water-cooking of broccoli on their antioxidant activity were observed.

Gökmen, V. , Bahçeci, K.S., Serpen, A., & Acar, J. (2005). Study of lipoxygenase and peroxidase as blanching indicator enzymes in peas: change of enzyme activity, ascorbic acid and chlorophylls during frozen storage. *Food Science and Technology*, 38, 903-908.

In this study, a re-evaluation of the use of lipoxygenase and peroxidase as indicator enzyme for optimizing the blanching conditions of peas was attempted in terms of the stabilities of some quality attributes such as ascorbic acid and chlorophylls during frozen storage.

The average ascorbic acid and dehydroascorbic acid contents (both compounds with vitamin C activity) of unblanched fresh peas were found to be 26.12 mg/100 g and 2.15 mg/100 g,

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respectively. AA and DHAA contents of peas decreased with 1,0% and 7,9% after blanching at 70°C for 4.0 min, and with 1,6% and 22,3% at 80°C for 2.0 min, respectively.
The loss of AA during frozen storage followed first order kinetics. The kinetic parameters There were significant differences between AA contents of unblanched and blanched pea samples after 12 months of frozen storage. The losses of AA were found to be 90.62%, 44.95% and 35.27% after 12 months in unblanched, 70°C for 4,0 min blanched and 80°C for 2,0 min blanched peas respectively.

Hart, D.J. & Scott, J. (1995). Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. ***Food Chemisfry 54,*** **101-111.**

This study further examines the factors which affect the chromatographic response of carotenoids and contribute to analytical variation and inaccuracies in their quantitative determination. A method for the analysis of carotenoids in vegetables and fruits is described and data are presented for the carotenoid content of vegetables and fruits commonly consumed in the UK. The addition of a solvent modifier (triethylamine) to the mobile phase was shown to improve the recovery of carotenoids from the column from around 60% to over 90%. The linearity and reproducibility of the chromatographic response was investigated and the robustness and reproducibility of the method was measured using a reference vegetable material developed in the laboratory. Short and longer term reproducibility showed an average CV of around 8% for all carotenoids. Analysis showed that good sources (>IOOO &IOO g) of lutein were broccoli, butterhead lettuce, parsley, peas, peppers, spinach and watercress; of lycopene: tomatoes and tomato products; and of p-carotene: broccoli, carrots, greens, butterhead lettuce, mixed vegetables, parsley, spinach and watercress. There was little or no loss of carotenoids on cooking, green vegetables showed an average increase in lutein levels of 24% and in p-carotene levels of 38%. This study and previous studies in our laboratory have demonstrated that a number of factors affect the validity of the 'peak response' and are likely to contribute to within and between laboratory variation. It is suggested that the development and use of standard reference materials would significantly improve the quality of data.

Hodges, D.M., Munro, K.D., Forney, C.F. and Mcrae, K.B. (2006). Glucosinolate and free sugar content in cauliflower (Brassica oleracea var. Botrytis cv. Freemont) during controlled-atmosphere storage. ***Postharvest Biology and Technology*****, 40, 123-132.**

The aim of the study is to investigate glucosinolate changes in cauliflower during air / controlled atmosphere storage.
Cauliflowers were placed into flatpack boxes and then stacked in stainless steel controlled atmosphere chambers and held at 0°C in the dark. They were exposed to either ambient air or a

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controlled atmosphere of 3% oxygen and 5% carbondioxide. Glucosinolate assays were performed on days 0, 14, 28, 42 and 56.
Total glucosinolate levels increased in cauliflower heads stored in air on day 28 and remained stable thereafter; total glucosinolate levels did not change between day 14 and 56 in the controlled atmosphere-stored cauliflower heads. There was no significant difference between the two storage treatments.

Hunter, K.J. and Fletcher, J.M. (2002). The antioxidant activity and composition of fresh, frozen, jarred and canned vegetables. *Innovative Food Science and Emerging Technologies*, 3, 399-406.

The total antioxidant activity was determined in water- and lipid-soluble extracts from fresh, stored and frozen vegetables. The contribution of individual compounds to total antioxidant activity was estimated.
After harvest, samples of peas and spinach were stored in plastic bags at 20 °C or at 4 °C or were blanched and frozen using an approximation of commercial conditions (peas: 85 s at 97 °C, then cooled with cold water for 90 s, frozen at -30 °C for 40 min, spinach: 90 s at 97 °C, then cooled with cold water for 90 s, frozen at -30 °C for 40 min). Blanching and freezing of peas and spinach reduced water-soluble antioxidant activity by 30 and 50 %, respectively, thereafter levels remained constant on storage at -20°C. The lipid-soluble antioxidant activity in both peas and spinach (ambient, chilled and frozen) remained stable up to 21 days of storage at either 4 or 20 °C and there was no effect of blanching and freezing.
When antioxidant activities were ranked for different processing methods for peas, they appeared in the order of frozen (76 % retention) > jarred (42 % retention) > canned (41 % retention). For spinach the ranking of total antioxidant activity was frozen leaf (76 % retention) > frozen chopped (52 % retention) > canned (26 % rentention). Appropiate cooking methods retain total antioxidant activity, although overcooking may result in substantial losses (40 % losses). Cooking methods could have an influence on ascorbic acid content: boiling leads to 25 % AA-losses, overcooking gave 74 % AA-losses.

Jiratanan, T. & Liu, R.H. (2004). Antioxidant activity of processed table beets (*Beta vulgaris var. conditiva*) and green beans *(Phaseolus vulgaris* L.). *Journal of Agricultural and Food Chemistry*, 52, 2659-2670.

One of the objectives of this study was to evaluate the effects of thermal processing on the nutritional quality of green beans by assessing the vitamin C content, dietary folate content, total phenolic content and total flavonoid content.
A homogeneous sample of raw beans was packed in cans with 150 ml distilled water. One group was subjected to 10, 20 or 40 min of heat at 115°C; another group was subjected to 100, 115 and 121°C for 20 min.

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Vitamin C retention in the green beans was 87,8, 93,8 and 95,9% for 10, 20 and 40 min of heating at 115°C respectively. The vitamin C retention for 20 min of heating at 100, 115 and 121°C was 99,8, 93,8 and 96,6% respectively.

Folic acid content of thermally processing green beans did not show any significant reduction in both treatment groups as compared to the unprocessed beans.

Initial thermal processing of green beans at 115°C for 10 min degraded approximately 40% of free total phenolic compounds. Further application of heat for 20 min, however did not result in further reduction of phenolic content in beans, but there was an increase after 40 min of processing when compared to the samples at 10 and 20 min.

Processsed green beans showed a significant decrease in free flavonoid content compared to the control. There was an initial 60% reduction of free flavonoid compounds in green beans processed for 10 min at 115°C as compared to the control. Treatments at 20 and 40 min also showed a significant decrease in flavonoids compared to the control. There were no significant differences among the three thermally processed groups.

Kala, A. & Prakash, J. (2006). The comparative evaluation of the nutrient composition and sensory attributes of four vegetables cooked by different methods. *International journal of Food Science and Technology*, 41, 163-171.

The nutritional composition of beans cooked in microwave oven were compared with conventional cooking and pressure cooking.

An amount of 600g of beans were cooked during 30, 25 and 25 min in 125, 100 and 150 ml water for conventional, pressure and microwave cooking respectively.

Dietary fibre content of the beans was found to be 40,13 g/100g on dry weight base. A decrease of dietary fibre content of 19,0, 8,4 and 11,5% was observed for conventional, pressure and microwave cooking respectively.

Calcium content of the beans was found to be 372 mg/100g on dry weight base. A decrease of calcium content of 1,3, 5,1 and 0% was observed for conventional, pressure and microwave cooking respectively.

Phosphorus content of the beans was found to be 352 mg/100g on dry weight base. A decrease of phosphorous content of 10,5, 0 and 0% was observed for conventional, pressure and microwave cooking respectively.

Iron content of the beans was found to be 8,95 mg/100g on dry weight base. A decrease of iron content of 6,5, 0 and 0,4% was observed for conventional, pressure and microwave cooking respectively.

Ascorbic acid content of the beans was found to be 126 mg/100g on dry weight base. A decrease of ascorbic acid content of 77,6, 90,1 and 87,4 was observed for conventional, pressure and microwave cooking respectively.

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Kalt, W. (2005). Effects of production and processing factors on major fruit and vegetable antioxidants. *Journal of Food Science*, 70 (1), R11-R19.

The aim of this review is to show how the health functionality of the diet may be improved by increasing and retaining the antioxidant content of fruits and vegetables through varietal selection and by controlling conditions of production, harvest, storage, and processing. A summary of the influence of handling and storage and processing on various fruits and vegetables is given.

Strawberries stored at 20°C lost between 55% and 70% of their ascorbic acid after only 4 d. Ascorbic acid content decreased between 25% and 30% in 3 apple varieties during 6 months of conventional storage. Unpacked broccoli florets lost between 75% and 85% of their vitamin C and 50 % of their carotenoid content after 6d of storage at 5°C. Green beans did not retain their vitamin C very well. After 16d of refrigerated storage, only 8% of the original ascorbic acid content was present. Apples stored at 1,5°C or 4°C retained their flavonoid phenolics throughout their storage life. In another study, apples stored at 5°C lost 257% of their total phenolic content after about 6 months.

Peas lost about 20% of their ascorbate during blanching, and there was no further loss during 21 d of frozen storage. When fresh spinach was boiled in water, approximately 60% of the vitamin C was found in the cooking water and 40% in the cooked tissue.

Kmiecik, W.; Lisiewska, Z.; Korus, A. (2007). Retention of mineral constituents in frozen brassicas depending on the method of preliminary processing of the raw material and preparation of frozen products for consumption. *European Food Research and Technology*, 224, 573–579.

The content of ash, P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, Cr and Ni was determined in four species of brassicas: Brussels sprouts, broccoli, and green and white cauliflowers. The investigation covered the rawmaterial, the material blanched or cooked before freezing and frozen products after 12 months of refrigerated storage and prepared for consumption. Frozen products were obtained by the traditional method of freezing the blanched material or by the modified method of freezing the cooked material. The processing of vegetables before freezing (washing, grinding, blanching or cooking) caused statistically significant decreases in most constituents analysed. Blanching did not basically change the content of sodium and calcium; or that of chromium in both types of cauliflower; copper and nickel in white cauliflower; and nickel and phosphorus in Brussels sprouts. Cooking in brine, however, caused increases in the content of ash, sodium and calcium in white cauliflower, decreases in the content of potassium and iron and, in some species, of the remaining constituents. In comparison with the traditional method, a greater content of most analysed elements was found in frozen products obtained by the modified technology and prepared for consumption. However, no significant differences were noted in the level of chromium in all the samples; in the level of calcium in broccoli and green cauliflower; of nickel in broccoli; of nickel, copper and zinc in white cauliflower; and of copper in green cauliflower.

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Leskova, E., Kubikova, J., Kovacikova, E., Kosicka, M, Porubska, J. & Holcikova, K. (2006). Vitamin losses: Retention during heat treatment and continual changes expressed by mathematical models. *Journal of Food Composition and Analysis*, 19, 252-276.

This paper reviews the existing knowledge on the vitamin stability during the culinary processes noted in literature.

β-carotene is more susceptible to degradation then α-carotene. Boiling seems to be the most damageable process (up to 67% losses). Highest retention was obtained when the vegetables were cooked without addition of water and that the lowest retention was associated with the use of a large amount of water during cooking. Also blanching of various vegetables can reduce the level of β-carotene by 7-20%. Blanching pretreatments ensure a good retention of β-carotene even for 12 months.

Vitamin C retention are highest in vegetables prepared by steaming (up to 99%), microwave steaming and stir-frying with oil, followed by stir-frying with water and finally boiling which caused the most extensive damage, with losses of up to 75%. Losses of vitamin C are minimal when vegetables are cooked without any water, while maximum losses are associated with cooking in a large amount of water. It was found that thawing before cooking causes more vitamin C loss. Therefore the author states that frozen vegetables should not be thawed before cooking. Blanching pretreatments ensure a good preservation during storage of frozen products and yields very good stability of vitamin C.

Folate is sensitive to sunlight, air, light and being heated in acid solutions. Folate is lost during cooking because it breaks down under heat and leaches into the cooking water. The highest retention was observed in non-leafy vegetables (up to 100%, except in boiled broccoli), whereas higher losses were observed during culinary treatment of legumes (up to 60% losses). Cooking methods that minimize direct contact of food with the cooking water, such as in pressure-cooking, microwave cooking, or stir-frying have been found to be preferable to boiling for folate retention.

Lin, S. & Brewer, M.S. (2005). Effects of blanching method on the quality characteristics of frozen peas. *Journal of Food Quality*, 28, 350-360.

In this study fresh peas were subjected to different blanching methods prior to freezing. Peas were shelled, then subjected to one of five treatments: No blanching (control); steam-blanched (4 min); boiling water immersion-blanched (4 min); microwave-blanched in a Pyrex beaker (80 ml of water; 4 min; 800 Watts) or microwave-blanched in a bag (80 ml of water, 4 min).

Ascorbic acid content was highest in fresh, unblanched peas which contained about 29 mg/100 g. Of the blanching treatments, steam-blanched peas had the highest AA content. Water-blanched peas retained the lowest (14 mg/100 g). The fact that steam-blanched peas had the next highest RAA content (22 mg/100 g) followed by those blanched by both microwave methods supports the contention that the amount of water used during blanching affects the amount of ascorbic acid lost

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due to leaching of the water-soluble compound into the blanch water After 6 and 12 weeks of frozen storage, steam-blanched peas consistently contained the most AA (17 and 19 mg/100 g, respectively), while boiling waterblanched peas contained the least (11 and 12 mg/100 g, respectively).

Lin, C.H. & Chang, C.-Y. (2005). Textural change and antioxidant properties of broccoli under different cooking treatments. *Food Chemistry*, 90, 9-15.

In this study, the effect of cooking treatments on the antioxidant properties of broccoli was investigated.

The samples were cooked by different methods: precooking at 50°C for 10 min, cooking in boiling water for 8 min and precooking followed by cooking. The antioxidant properties (reducing power, % ferrous ion chelating activity, % DPPH scavenging activity and antiperoxidation activity) of the methanolic extracts were determined after the different cooking treatments.

Broccoli with precooking and / or cooking treatments exhibited higher reducing powers than the fresh sample. The extracts from fresh and precooked broccoli had the highest ferrous ion chelating ability at around 90%, the extract from precooked + cooked broccoli had a ferrous ion chelating power of 82.5%; the extract from cooked broccoli had the lowest ferrous ion chelating power at 79%. The extract from fresh broccoli exhibited a DPPH scavenging activity of 71%; the extracts from cooked and precooked + cooked samples exhibited a scavenging activity of 50%. The extract from the precooked sample showed the lowest scavenging activity of 31%. The extract from the cooked sample had the highest anti-peroxidation activity (0.41 times that of BHA and α tocopherols). The extracts from fresh and precooked + cooked broccoli had 0.23 times the anti-peroxidation activity. The extract from precooked broccoli had almost no anti-peroxidation activity.

Lombard, K., Peffley, E., Geoffriau, E., Thompson, L. & Herring, A. (2005). Quercetin in onion (*Allium cepa* L.) after heat-treatment simulating home preparation. *Journal of Food Composition and Analysis*, 18, 571-581.

The objectives of this research were to determine: if cooking of bulb onions by sautéing, baking, and boiling affect quercetin concentrations, and if quercetin concentration responses to cooking method vary among onion cultivars.

For sautéing: onion quarters were sliced into 1-cm squares and sautéed for 1 min in oil preheated to 93°C. For baking: onion quarters were placed separately into ceramic cooking containers and baked for 15 min in a pre-heated rotisserie oven at 176°C. For boiling: onion quarters were placed in boiling distilled water for 5 min.

For sautéing and baking a gain of quercitin content (sum of 3,4'-quercetin-O-diglucoside and 4'-quercetin-O-glucoside) was observed: 25% gain for sautéing and 7% for baking. For boiling 18% reduction of quercitin content was observed.

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Masrizal, M.A., Giraud, D.W. & Driskell JA. (1997). Retention of vitamin C, iron and beta-carotene in vegetables prepared using different cooking methods. *Journal of Food Quality*, 20 (5), 403-418.

The retentions of β-carotene in vegetables cooked by household microwave steaming, stir-frying with oil or water, and boiling to the same degree of overall acceptance were compared.

The greatest mean β-carotene retention was observed in green beans, followed by spinach, Nappa cabbage and water spinach. Greater retention of β-carotene was obtained in vegetables prepared by microwave steaming and stir-frying with oil than those stir-fried with wzter or boiled.

Mayer-Miebach, E., Behsnilian, D., Regier, M. & Schuchmann, H.P. (2005). Thermal processing of carrots: lycopene stability and isomerisation with regard to antioxidant potential. *Food Research International*, 38, 1103-1108.

This work aims to evaluate lycopene stability in a carrot cultivar with a high lycopene content (Daucus carota var. Nutri Red) as affected by thermal treatment.

Heat treatment at temperatures below 70°C did not affect all-trans-lycopene contents of homogenised carrots even after heating times up to 5 h. After heating at 100 and 140°C for 2 h, 75% and 25% of all-trans-lycopene remained stable respectively.

McKillop, D.J., Pentieva K., Daly D., McPartlin J.M., Hughes J., Strain J.J., Scott J.M. & McNulty, H. (2002). The effect of different cooking methods on folate retention in various foods that are amongst the major contributors to folate intake in the UK diet. *British Journal of Nutrtion*, 88 (6), 681-688.

Folate intake is strongly influenced by various methods of cooking that can degrade the natural forms of the vitamin in foods. The aim of the present-study was to determine the effect of different cooking methods on folate retention in various foods that contribute to folate intake in the UK diet. Boiling for typical time periods resulted in only 49 % retention of folate in spinach (191.8 and 94.4 µg/100g for raw and boiled (3,5 min) spinach respectively), and only 44 % in broccoli (177.1 and 77.0 µg/100 g for raw and boiled (10 min) broccoli respectively). Steaming of spinach or broccoli, in contrast, resulted in no significant decrease in folate content, even for the maximum steaming periods of 4.5 min (spinach) and 15.0 min (broccoli). These current results show that the retention of folate in various foods is highly dependent both on the food in question and the method of cooking. Thus, public health efforts to increase folate intake in order to improve folate status should incorporate practical advice on cooking.

McNaughton, S.A. & Marks, G.C. (2003). Development of a food composition database for the estimation of dietary intakes of glucosinolates, the biologically active constitutents of cruciferous vegetables. *British Journal of Nutrition*, 90, 687-697.

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This review provides a database for the glucosinolate content of cruciferous vegetables, based on eighteen published studies covering 140 estimates for 42 items (different vegetables, different processing and storage conditions).

Most of the data considered in the review deals with fresh vegetables. In previous literature, it has been suggested that calculating estimates of glucosinolate intake on values obtained from fresh vegetables provides an indication of the maximum possible intake. However, it is well known that glucosinolates are lost from vegetables during processing such as storage, cutting and cooking. This review therefore also reports limited data for cooked cruciferous vegetables, showing that the average glucosinolate losses during cooking are approximately 36%.

The following individual results for raw vegetables are reported in the review:

- The glucosinolate content of broccoli was found to be 62 mg/100g (average) and to range from 19 to 128 mg/100g (6 references). Frozen broccoli (1 reference) contained on the average 51 mg/100g glucosinolates.
- The glucosinolate content of Brussels sprouts was found to be 237 mg/100g (average) and to range from 80 to 445 mg/100g (8 references). Frozen Brussels sprouts (1 reference) contained on the average 90 mg/100g glucosinolates.
- Cabbage contained on the average 59 mg/100g glucosinolates (range: 43-109 mg/100g, 3 references). The respective glucosinolate content is 64 mg/100g (range: 27-77 mg/100g, 5 references) for red cabbage, 77 mg/100g (range: 60-209 mg/100g, 3 references) for savoy and 38 mg/100g (range: 8-90 mg/100g) for white cabbage.
- Cauliflower contained on the average 43 mg/100g glucosinolates (range: 12-79 mg/100g, 5 references) while frozen cauliflower contained 41 mg/100g glucosinolates.

With respect to the glucosinolate content in the fresh vegetables, cooking or boiling overall lead to losses in glucosinolate content. Glucosinolate retention through cooking or boiling was 61% for broccoli, 41% for frozen broccoli, 55-60% for Brussels sprouts, 68% for frozen Brussels sprouts, 72% for cabbage, 82% for red cabbage, 68% for cauliflower and 69% for frozen cauliflower.

Melse-Boonstra, A., Verhoef, P., Konings, E.J.M., Van Dusseldorp, M., Matser, A., Hollman, P.C.H., Meyboom, S., Kok, F.J. & West, C.E. (2002). Influence of processing on total, monoglutamate and polyglutamate folate contents of leeks, cauliflower, and green beans. *Journal of Agricultural and Food Chemistry*, 50, 3473-3478.

Total folate loss (expressed on dry weight) of cauliflower and green beans after various processing treatments

Treatment	Total (% loss)
Stored (4°C, 24h) cauliflower	15

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Stored green beans (4°C, 24h)	-7
Blanched cauliflower (8 min)	10
Blanched green beans (6 min)	21
Steamed cauliflower (7 min)	8
Steamed green beans (6 min)	10
Frozen (-18°C, 16h), thawed (4°C, 24h), blanched (8 min) cauliflower	65
Frozen (-18°C, 16h), thawed (4°C, 24h), blanched (6 min) green beans	79
Blanched (8 min), frozen (-18°C, 16h), thawed (4°C, 24h) cauliflower	16
Blanched (6 min), frozen (-18°C, 16h), thawed (4°C, 24h) green beans	35

Moreno, D.A.; L'opez-Berenguer, C.; Garcïa-Viguera, C. (2007). Effects of stir-fry cooking with different edible oils on the phytochemical composition of broccoli. *Journal of food science*, 72, S64-S68.

Numerous epidemiologicalstudies indicate that Brassica vegetables in general and broccoli in particular protect humans against cancer; they are rich sources of glucosinolates and posses a high content on flavonoids, vitamins, and mineral nutrients. The contents of total intact glucosinolates, total phenolics, vitamin C, and minerals (potassium, sodium, calcium, magnesium, iron, manganese, zinc, and copper) in the edible portions of freshly harvested broccoli (florets), which was subjected to stir-frying treatments, were evaluated. In the present work, the stir-fry cooking experiments were carried out using different edible oils from plant origin (refined olive oil, extra virgin olive oil,

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sunflower oil, peanut oil, soyabean oil, and safflower oil) known and used worldwide. Results showed that during stir-frying, phenolics and vitaminC were more affected than glucosinolates and minerals. Stir-fry cooking with extra virgin olive, soybean, peanut, or safflower oil did not reduce the total glucosinolate content of the cooked broccoli compared with that of the uncooked sample. The vitamin C content of broccoli stir-fried with extra virgin olive or sunflower oil was similar to that of the uncooked sample, but greater than those samples stir-fried with other oils.

Ninfali, P. & Bacchiocca, M. (2003). Polyphenols and antioxidant capacity of vegetables under fresh and frozen conditions. *Journal of Agricultural and food chemistry*, 51, 2222-2226.

In this study total phenolics and total antioxidant capacity (expressed as oxygen radical absorbance capacity ORAC) of some fresh and frozen vegetables (spinach, broccoli, carrot, onion) were measured.

Freezing of the fresh vegetables resulted in the following reduction of phenolic content: 32,9% for spinach, 58,4% for broccoli and 59,6% for carrots. Frozen onions had a higher total phenols content then fresh onions, 52,32 mg/100g and 24,40 mg/100g respectively.

Freezing of the fresh vegetables resulted in the following reduction of antioxidant capacity: 42,7% for spinach, 12,4% for broccoli and 47,5% for carrots. Frozen onions had a higher antioxidant capacity then fresh onions, 707,58 µmol Trolox Equivalent/g of dry tissue (ORAC value) and 540,26 µmol Trolox Equivalent/g of dry tissue (ORAC value) respectively.

The overall results suggest that people who use frozen vegetables will have a 30-50% drop in antioxidant capacity with respect to the people who eat an identical amount of fresh vegetables.

Nisha, P., Rekha, S.S., and Aniruddha, B.P., (2005). A study on degradation kinetics of riboflavin in spinach (*Spinacea oleracea L.*). *Journal of Food Engineering*, 67, 407-412.

The main objective of this study was to determine the kinetic parameters for riboflavin degradation in spinach over a temperature range of 50-120 ^{o}C (steady state) and a study of the degradation kinetics of riboflavin for different cooking methods (unsteady state). The normal open pan cooking (20 min at a gas flow rate of 15 ml/s), pressure cooking (15 min at 15 ml/s) and the new developed slow cooker 'Ecocooker'(30 min at a gas flow rate of 4.5 ml/s and 30 min holding period) were selected.

The retention of riboflavin after a heat treatment ranged from 99 % (50 °C during 10 minutes) to 77 % (120 °C during 60 minutes). The retentions for the different cooking methods were as follows: 96 % for open pan cooking, 95 % for pressure cooking and 88 % for Ecocooking.

Nunn, M.D.; Giraud, D.W.; Parkhurst, A.M.; Hamouz, F.L.; Driskell, J.A. (2006). Effects of cooking methods on sensory qualities and carotenoid retention in selected vegetables, *Journal of Food Quality*, 29, 445–457.

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The effects of induction boiling, conventional boiling and microwave steaming on the sensory qualities and carotenoid retention of broccoli, carrots, green beans and sweet potatoes were investigated. Significantly higher cooking yields were obtained for vegetables that were induction and conventionally boiled. No differences in the retentions of alpha-carotene (a-carotene), beta-carotene (b-carotene) and lutein/zeaxanthin were observed for vegetables by the cooking method, with the exception of b-carotene retention in broccoli and sweet potatoes where retentions were higher for those that were induction boiled (90.3 and 86.1%, respectively) than those that were microwave steamed (62.2 and 66.4%, respectively). A trained panel judged the color scores of three vegetables by the cooking method as similar. The mean flavor scores (1 = extremely bland; 9 = extremely intense) for three vegetables that were conventional (4.7–5.4) and induction (5.3–5.5) boiled were lower than those that were microwave steamed (5.9–7.0). The mean texture scores (1 = extremely mushy/tender; 9 = extremely firm/tough) for all induction-boiled (5.0–6.0) vegetables were higher than those that were conventionally boiled (3.4–5.2) and lower than those that were microwave steamed (5.1–6.6).

Nursal, B. & Yucecan, S. (2000). Vitamin losses in some frozen vegetables due to various cooking methods. *Nahrung-Food*, 44 (6), 451-453.

Frozen spinach, peas, green beans and okra were commercially cooked in three different stewpans (double based stainless steel, teflon, pyrex) with and without thawing. The vitamin C levels were effected both by cooking methods and stewpans. Frozen peas were found to be the least (3,5% loss), and frozen green beans were found to be the most (19,6% loss) effected vegetables by thawing. In all of the stewpans, double based stainless steel pan retained more vitamin C than the others. While boiling spinach, peas, green beans, and okra without thawing resulted 46.5, 25.2, 18,2, and 21,6% vitamin C loss in double based stainless steel pan, boiling them in pyrex pan resulted 58,5, 36,0, 42,1, and 28,2% vitamin C loss, respectively. Besides, the losses in cooking processes were accelerated in thawed vegetables with the same tendency; that is more destruction occurred in samples boiled in pyrex pan (60,3% loss in spinach, 40,8% loss in peas, 48,4% loss in green beans, and 41,6% loss in okra). According to the results, it was found that thawing before cooking is useless and causes more vitamin C loss. Therefore, frozen vegetables must not be thawed before cooking. In order to prevent vitamin C from destruction, using double based stainless steel pan, minimum amount of water and cooking of frozen vegetables are recommended.

Oerlemans, K., Barrett, D.M., Bosch Suades, C., Verkerk, R. & Dekker, M. (2006). Thermal degradation of glucosinolates in red cabbage. *Food Chemistry*, 95, 19-29.

This paper studies thermal degradation of individual glucosinolates within the plant matrix: red cabbage samples were heated at different temperatures for various times. Based on these results, a

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first-order thermal degradation model for individual glucosinolates was developed. Using this model and the derived kinetic parameters for the individual glucosinolates in red cabbage, the effects of standardised conditions for blanching, cooking and canning on all individual glucosinolates were predicted. In this prediction, only losses due to thermal breakdown are given, e.g., losses due to leaching into the blanching, cooking or canning water have not been included.
The predictions show that mild treatments, such as blanching (3 minutes at 95 °C), have little impact on the glucosinolates (about 100% retention). Conventional cooking (40 minutes at 100 °C) resulted in 89% retention of total glucosinates. The more severe heat treatments such as canning (40 minutes at 120 °C) severely affects all glucosinates as a retention of only 27% was predicted.
The losses of glucosinolates observed in literature are substantially higher than the predicted values after a similar heat treatment in this study. Higher losses reported in literature will very likely be due to leaching of components in the cooking water used and possibly enzymatic degradation of glucosinolates.

Pandrangi, S. and Laborde, L.F. (2004). Retention of folate, carotenoids, and other quality characteristics in commercially packaged fresh spinach. *Journal of Food Science*, 69, 702-707.
The effect of storage temperature (4 °C, 10 °C and 20 °C) and time on retention of folate, carotenoids, and other quality characteristics in commercially packaged fresh spinach were determined. Harvested spinach leaves are transported over long distances in refrigerated trucks to the processing facility where they are sorted, washed, centrifuged to remove surface moisture, and packaged in plastic bags. Spinach in the sealed bags and spinach leaves removed from bags were placed in temperature-controlled stainless-steel chambers for storage at 4 °C, 10 °C or 20 °C.
Substantial losses of nutrients occurred at each storage temperature. Only 53 % of folate in packaged spinach was retained after 8 d, 6 d, and 4 d at 4°C, 10 °C and 20 °C, respectively. Carotenoid losses increased with temperature with only 54 %, 61 % and 44 % remaining carotenoids, respectively.
It is essential that growers, packers, fresh-cut processors, and retailers maintain storage temperatures as low as possible to minimize vitamin losses in fresh spinach.

Punna, R. & Paruchuri, U.R. (2004). Effect of maturity and processing on tatal, insoluble and soluble dietary fiber contents of Indian green leafy vegetables. *International Journal of Food Sciences and Nutrition*, 55 (7), 561-567.
The present study was undertaken to generate data on total (TDF), insoluble (IDF) and soluble (SDF) dietary fibre contents of green leafy vegetables.
Cooking of a known quantity spinach in an equal amount of water for 10 min in a pressure cooker had no significant effect on TDF, IDF and SDF content of the spinach.

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Ramesh, M.N., Wolf, W., Tevini, D. & Bognar, A. (2002). Microwave blanching of vegetables. *Journal of Food Science*, 67 (1), 390-398.

One of objectives of this study was to evaluate the vitamin C and carotene retention in microwave blanching in comparison with water blanching of spinach, bell peppers and carrots.

To compare the microwave blanching results with that of conventional blanching with water, the heat input in terms of temperature should be comparable. To obtain this condition, a pulsed method of keeping the magnetron power ON for an initial period of 30 s to attain the targeted temperature and then putting ON and OFF for 5 s was used.

For spinach, 50g of the product was microwave blanched during 3,2 min using the pulsed method and 50 g was blanched in 2,5l water at 98±2°C during 1,5 min. Vitamin C retention was 68,9% and 51,0% for microwave and water blanching respectively.

For bell peppers, 50g of the product was microwave blanched during 4,8 min using the pulsed method and 50 g was blanched in 2,5l water at 98±2°C during 4,5 min. Vitamin C retention was 84,7% and 76,2% for microwave and water blanching respectively.

For carrots, 50g of the product was microwave blanched during 2,0 min using the pulsed method and 50 g was blanched in 2,5l water at 98±2°C during 2,0 min. Vitamin C retention was 82,6% and 49,1% for microwave and water blanching respectively. Carotene retention was 56,9% and 21,2% for microwave and water blanching respectively.

It could be concluded that vegetables blanched with microwave energy were more nutritious than those heated to the same temperature by conventional water blanching.

Rangkadilok, N., Tomkins, B., Nicolas,M.E., Premier, R.R., Bennett, R.N., Eagling, D.R. & Taylor, P.W.J. (2002). The effect of post-harvest and packaging treatments on glucoraphanin concentration in broccoli (Brassica oleracea var. italica). *Journal of Agricultural and Food Chemistry*, 50, 7386-7391.

The objective of this work was to investigate the effects of storage conditions on glucoraphanin (most important beneficial glucosinolate in broccoli) concentration in broccoli after harvest. The effects of storage temperature, storage under air or controlled atmosphere conditions, as well as storage in modified atmosphere packaging (MAP) were examined.

The aim of the first experiment was to study the effect of temperature (4°C and 20°C) and packaging (perforated LDPE minimizing moisture loss and creating a high humidity storage environment and open boxes at ambient humidity). At 20°C, glucoraphanin concentration (expressed per g dry weight) in broccoli stored in plastic bags had decreased significantly by day 7 (56% loss) while the concentration in broccoli stored in open boxes declined significantly during the first 3 days of the treatment (55% loss). In contrast, there were no significant differences in glucoraphanin concentration in broccoli stored in plastic bags and open boxes at 4°C during 7 days of storage.

The aim of the second experiment was to study the effect of air and controlled atmosphere (CA) storage (1.5% oxygen and 6% carbondioxide filled up with nitrogen) at 4°C while the broccoli was

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stored in LDPE bags. Glucoraphanin concentration in broccoli heads appeared to fluctuate slightly during 25 days of storage under both air and CA. There were no significant changes during the storage time although the concentration was significantly higher in the broccoli under CA.
The aim of the third experiment was to study the effect of MAP packaging. Four treatments were compared: MAP (LDPE bags without holes) at 4°C, MAP (LDPE bags with two microholes) at 20°C and standard air control treatment at 4°C and 20°C. Glucoraphanin concentration decreased by 30% in broccoli stored in air control packaging at 4°C during the first 3 days and then slightly increased at the end of storage time. A large decrease occurred in broccoli stored in air control packaging at 20°C with 48% loss at day 3 and 64% loss at day 10. In contrast, there were no significant changes in glucoraphanin concentration in broccoli heads stored for up to 10 days in MAP with no holes at 4°C and two microholes at 20°C.

Rehman, Z.U., Islam, M. & Shah, W.H. (2003). Effect of microwave and conventional cooking on insoluble dietary fibre components of vegetables. *Food Chemistry*, 80, 237-240.
The present study was undertaken to investigate the effects of different cooking methods on insoluble dietary fibre components of various vegetables (cabbage, carrot, cauliflower, onion, peas and spinach).
Chopped vegetables were cooked for 10min, pressure cooked for 10 min or microwaved for 10 min. The amount of each dietary fibre component (NDF(neutral detergent fibre), ADF (acid detergent fibre), cellulose, hemi-cellulose, lignin) was determined in 10 raw and cooked vegetables on a dry basis. The raw vegetables contained 11,3–34,1 g/kg NDF and 9,6–28,2 g/kg ADF, whereas the amounts of cellulose, hemicellulose and lignin contents were 7,0–18,2, 1,1–5,9 and 0,9–10,0 g/kg, respectively. The contents of NDF and ADF of each vegetable were significantly reduced on cooking. Ordinary cooking reduced (7,7–22,6%) NDF in these vegetables whereas pressure-cooking and microwave cooking caused reduction in NDF contents of 22,6–38,8 and 13,4–28,5%, respectively. Similarly ADF contents were reduced by 10,9–19,3% when vegetables were cooked by the ordinary method. However, pressure-cooking and microwave cooking reduced ADF contents in these vegetables by 18,1–33,6 and 12,3–27,6%, respectively. The reductions in NDF and ADF contents were distinctly higher in the case of pressure-cooking than the other two cooking methods.
The cellulose, hemicellulose and lignin contents were signifcantly reduced, to various extents, when vegetables were cooked by three different methods. However, pressure-cooking showed more reduction of these dietary fibre components than ordinary and microwave cooking methods. As a result of pressure cooking, 24,4–43,8% of the cellulose and 31,3–47,4% of the hemicellulose were reduced in these vegetables. It is apparent from these findings that reduction in hemicellulose was comparatively greater than that of cellulose on cooking the vegetables. However, lignin contents remained almost unchanged on cooking by these three methods. In general, the observed effect of cooking process on individual dietary fibre components in the vegetables depended, not only on the type of vegetable, but also on the cooking method involved.

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Serrano, M., Martinez-Romero, D., Guillen, F., Castillo, S. And Valero, D. (2006). Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging. *Postharvest Biology and Technology*, 39, 61-68.

The effect of different modified atmospheres by using three distinct types of polypropylene films (macro-perforated (0.06-0.08 kPa carbondioxide and 20 kPa oxygen at steady state), micro-perforated (2.0-2.5 kPa carbondioxide and 14 kPa oxygen at steady state) and non-perforated (6 kPa carbondioxide and 5 kPa oxygen at steady state)) on the change in several parameters related to broccoli quality (total antioxidant activity, total phenolic compounds and ascorbic acid determination expressed on dry weight basis) were studied during 28 days of cold storage (1°C, 90% RH).

The total antioxidant activity diminished continuously over the 20 days of cold storage in control heads at which half of the initial activity was detected. For all MAP broccoli, the total antioxidant activity was maintained during the experiment and only a slight decrease was observed for heads packed in macro-perforated film after 28 days of storage. A similar behaviour for the change in total phenolic compounds was observed, that is a sharp decrease (40%) in control heads and maintenance in those stored under MAP, especially for micro-perforated and non perforated films. Ascorbic acid decreased progressively over storage, the diminution being significantly higher in unwrapped broccoli (decrease from 2.15 to 1.45) than in those under MAP. Among these, ascorbic acid retention at the end of the storage period was higher in broccoli packaged in microperforated or non perforated film (1.85 and 1.72 respectively) than in macroperforated film (1.55).

Song, L. & Thornalley, P.J. (2007). Effect of storage, processing and cooking on glucosinolate content of Brassica vegetables, *Food and Chemical Toxicology* 45, 216–224.

Epidemiological studies have shown that consumption of Brassica vegetables decrease the risk of cancer. These associations are linked to dietary intake of glucosinolates and their metabolism to cancer preventive isothiocyanates. Bioavailability of glucosinolates and related isothiocyanates are influenced by storage and culinary processing of Brassica vegetables. In this work, the content of the 7 major glucosinolates in broccoli, Brussels sprouts, cauliflower and green cabbage and their stability under different storage and cooking conditions is examined. Glucosinolates and isothiocyanates were quantified by liquid chromatography with tandem mass spectrometric detection (LC–MS/MS). Isothiocyanates were detected with high sensitivity as the corresponding thiourea derivatives. Storage at ambient temperature and in a domestic refrigerator showed no significant difference and a minor loss (9–26%) of glucosinolate levels over 7 days. Vegetables shredded finely showed a marked decline of glucosinolate level with post-shredding dwell time – up to 75% over 6 h. Glucosinolate losses were detected partly as isothiocyanates. Cooking by steaming, microwaving and stir-fry did not produce significant loss of glucosinolates whereas boiling showed significant losses by leaching into cooking water. Most of the loss of the glucosinolates (~90%) was detected in

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the cooking water. Increased bioavailability of dietary isothiocyanates may be achieved by avoiding boiling of vegetables.

Starzynska, A., Leja, M. & Mareczek, A. (2003). Physiological changes in the antioxidant system of broccoli flower buds senescing during short-term storage, related to temperature and packaging. *Plant Science*, 165, 1387-1395.

The aim of this research was to provide information about the proceses occurring during different ways of storage of broccoli in darkness. Broccoli was stored at 5°C and 20°C and non-packaged and packaged in LDPE foil. The amount of soluble phenols scavenging free radicals was determined by means of the DPPH decoloration test (antiradical activity). Furthermore the phenylpropanoid and flavonoid levels were determined.

During the storage of inflorescences at 20°C a gradual increase of antiradical activity was measured. In samples taken from broccoli heads kept at 5°C no rise of the antiradical activity was detected during the whole storage period. Higher antiradical activity in buds taken from non-packaged broccoli heads than from the packaged ones was observed only at 20°C treatment. Storage induced accumulation of phenylopropanoids and flavonoids. In case of storage at 5°C the increase was only found after 7 days of storage. During storage at 20°C, packaging decreased the accumulation of phenylopropanoids and flavonoids. The total soluble phenols slightly increased during storage at 5°C (25% for non packaged and 30% for packaged) and increased more pronounced (70% for non packaged and 50% for packaged) during storage at 5°C.

Turkmen, N, Sari, F., Velioglu, Y.S. (2005). The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. *Food Chemistry*, 93, 713-718.

Green beans, peas, pepper, squash, broccoli, leek and spinach are common vegetables consumed as cooked. However, very little information is available in the literature regarding the antioxidant activity and total phenolics of these vegetables. Therefore, the present study
was undertaken to investigate the effects of different cooking methods on antioxidant activity and total phenolics of the vegetables.

For boiling vegetable (100 g) was added to 150 ml of water that had just reached the boil in a stainless steel pan and cooked for 5 min. The samples were drained off and cooled rapidly on plenty of ice. For microwave cooking vegetable (100 g) was placed in a glass dish and 6 ml (12 ml for green beans) of distilled water was added. Dish were covered with cooking bag, having several holes, and cooked in a commercial – 1000 W microwave oven. Cooking took 1 min for squash, spinach, peas and 1.5 min for leek, broccoli, pepper and green beans. Samples were drained off and cooled rapidly on ice. For steaming the vegetables were placed on a tray in a steam cooker covered with lid and steamed over boiling water for 7,5 min under atmospheric pressure. The samples rapidly cooled on ice.

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The effect of cooking methods on total phenolic content (expressed as mg gallic acid equivalents (GAE)/100g dry weight) of vegetables:

Vegetable	Total phenolics retention (%) after		
	Boiling	Steaming	Microwaving
Pepper	114	102	126
Squash	60	70	67
Green beans	114	130	129
Peas	76	88	83
Leek	64	85	82
Broccoli	94	118	125
Spinach	101	103	109

Cooking was found to give rise to an increase in phenolics in green beans, pepper, spinach and broccoli. It was reported that heat treatment increased the level of free flavonols.

The effect of cooking methods on antioxidant activity (determined using DPPH method, Zhang & Hamauzu, 2004) of vegetables:

Vegetable	Total antioxidant activity retention after		
	Boiling	Steaming	Microwaving
Pepper	138	138	138
Squash	125	164	106
Green beans	162	185	188
Peas	84	95	90
Leek	80	121	115
Broccoli	116	117	117
Spinach	129	127	127

Cooking had no deleterious effect on total antioxidant activity and total phenolics content of vegetables with the exception of some losses of phenolics in only squash, peas and leek. Moreover, moderate heat treatment might have been considered a useful tool in improving health properties of some vegetables.

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Stea, T.H.; Johansson, M.; Jägerstad, M.; Frølich, W. (2006). Retention of folates in cooked, stored and reheated peas, broccoli and potatoes for use in modern large-scale service systems. *Food Chemistry*, 101, 1095–1107.

This study aimed to evaluate retention of folate in vegetables caused by different processes used in modern large-scale service systems and the food industry. The concentration of folates present in raw samples of peas, broccoli and potatoes was measured during different cooking methods, warm and cold holding and reheating. The main folate forms in vegetables, tetrahydrofolates and 5-methyltetrahydrofolates, were analysed using a validated high-performance liquid chromatography (HPLC) method. This study shows the following decreasing order in folate retention, on DM basis, compared to raw potatoes during heat-processing: sous-vide (103%), boiling (72–59% (unpeeled and peeled)) and oven-baking (63%) and compared to raw green peas during heat processing: boiling (77%), microwaving (75%), steam boiling (73%) and blanching (71%). However, only blanching of peas, boiling of potatoes and oven-baking of unpeeled potatoes caused significant reduction. Storage at various temperatures and length of times followed by reheating caused no further significant losses of total folate.

Vallejo, F., Tomas-Barberan, F.A. and Garcia-Viguera, C. (2002). Glucosinolates and vitamin C content in edible parts of broccoli florets after domestic cooking. *European Food Research and technology*, 215, 310-316.

The purpose of this work was the quantification of the glucosinolates and vitamin C in broccoli florets before and after cooking (high pressure boiling, steam cooking, microwaving and conventional boiling). Boiling and steam cooking were applied using a pressure cooker containing 150 g of fresh cut raw broccoli and 150 ml of tap water, using two different pressure valves for high and low pressure. Florets were fully dipped in water for 3 minutes for high pressure cooking, 5 minutes for conventional cooking, whereas they were placed above the boiling water for 3.5 minutes for steam cooking. A microwave oven at full power (1000W) for 5 minutes was used for microwaving.

Domestic cooking reduced the total glucosinolate content (expressed on dry weight) of the edible part of broccoli by over 50% (except steaming). Microwaving caused a great loss (about 74%) in total glucosinolate content. The loss rate in the other treatments varied between -7% in steam cooking, 52% in high pressure boiling and 74% in conventional boiling. More or less the same loss rates were obtained for the total aliphatic glucosinolate level. The degradation of indolyl glucosinolates also followed the same trends but with higher losses than for aliphatic glucosinolates. This is due to the higher thermolability of these compounds since the diffusion into the cooking water was quite similar.

Domestic cooking reduced vitamin C (AA and DHAA) content by between 20% and 46% (except steaming). Microwaving caused the greatest loss (about 46%).

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Vallejo, F., Tomas-Barberan, F. and Garcia-Viguera, C. (2003a). Health-promoting compounds in broccoli as influences by refrigerated transport and retail sale period. *Journal of Agricultural and Food Chemistry*, 51, 3029-3034.

The purpose of this work was to study the effect of MAP conditions on the postharvest behaviour of health promoting compounds (glucosinolates (expressed on dry weight), phenolic compounds (expressed on fresh weight) and vitamin C (expressed on fresh weight)) present in the edible portions of fresh harvested broccoli during simulated transport, distribution and retail sale periods.

Inflorescences were forced air-cooled to reach 10°C in 4 h and then wrapped in LDPE at 10°C. They were stored for 7 days at 1°C and 95% RH (simulation of refrigerated transport and distribution) followed by 3 days at 15°C and 70-75% RH (simulation of retail sale).

Total glucosinolates presented a high loss rate (71%) during cold storage in comparison with the amount at harvest. Total flavonoid content decreased up to 61% of that measured at harvest. The levels of vitamin C slightly decreased (2.4% loss) when compared with the initial values.

After the retail sale period the flavonoid content was slightly higher than after the cold storage period, probably due to the weight loss that led to compound concentrations in the cells. The total glucosinolate content decreased with an extra 9% during this period and the vitamin C level decreased with an extra 11%.

Vallejo, F., Tomas-Barberan, F.A. and Garcia-Viguera, C. (2003b). Phenolic compound contents in edible parts of broccoli inflorescences after domestic cooking. *Journal of the Science of Food and Agriculture*, 83, 1511-1516.

In this study the changes in flavonoids and phenols (sinapic, feruloyl acid and caffeoyl-quinic acid derivatives) (expressed as mg /kg broccoli fresh weight) in the edible portions of freshly harvested broccoli before and after cooking (high-pressure boiling, steaming, microwaving and conventional boiling) were determined.

Boiling and steam cooking were applied using a pressure cooker containing 150 g of fresh cut raw broccoli and 150 ml of tap water, using two different pressure valves for high and low pressure. Florets were fully dipped in water for 3 minutes for high pressure cooking, 5 minutes for conventional cooking, whereas they were placed above the boiling water for 3.5 minutes for steam cooking. A microwave oven at full power (1000W) for 5 minutes was used for microwaving.

The high-pressure boiling lead to a retention of 47% total flavonoids and 56% phenolics. Conventional cooking lead to a retention of 19% of total flavonoids and 46% of phenolics. Higher losses of flavonoids were thus detected for conventional cooking compared to high pressure cooking. This was due to the effect of high pressure, which reduced the cooking time required and therefore minimised the time of contact between the broccoli and the water. Thus, to minimise these losses, smaller amounts of water should be used. Steaming led to the highest phenolic compound levels (97%) and flavonoids (89%) in the edible part after cooking. Microwave treatment led to the

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highest losses of phenolic compounds. 97 and 80% losses for total flavonoids and phenolics respectively.

Viña, S.Z.; Mugridge, A.;Garcı´a, A.; Ferreyra, R.M.; Martino, M.N.; Chaves, A.R.; Zaritzky, N.E. (2007). Effects of polyvinylchloride films and edible starch coatings on quality aspects of refrigerated Brussels sprouts, *Food Chemistry* 103, 701–709.

To extend shelf life, the effects of polyvinylchloride film (PVC) and edible coatings on quality aspects of refrigerated Brussels sprouts were studied. Starch-based coatings were formulated using glycerol (G), sorbitol (S) or glycerol plus sunflower oil (O). Sprouts so treated as well as uncoated ones were placed on expanded polystyrene trays. Combinations of PVC and coatings (treatments named G-PVC, S-PVC and O-PVC) were also tested. Uncovered trays were maintained as controls. All packages were stored at 0 ┐ C for 42 days and samples were removed every 14 days to determine commercial acceptability, weight loss, surface colour (of sprouts' heads and bases) and texture. Sprouts in all treatments maintained optimum quality conditions over the first 14 days. At the end of storage, browning of cut zones and losses in weight and firmness were minimised in PVC-packaged sprouts, particularly in G-PVC. Therefore, PVC and G-PVC treatments were selected to evaluate some nutritional quality components. Ascorbic acid and total flavonoid contents remained almost constant while radical scavenging activity increased after 42 days of storage. Thus, PVC and G-PVC treatments showed the best performance for long-term refrigerated storage of Brussels sprouts.

Viña, S.Z.; Olivera, D.F.; Marani, C.M.; Ferreyra R.M.; Mugridge, A.; Chaves, A.R.; Mascheroni, R.H. (2007) Quality of Brussels sprouts (Brassica oleracea L. gemmifera DC) as affected by blanching method. *Journal of Food Engineering* 80, 218–225.

In this work, pre-blanching of Brussels sprouts was performed – using different heating media – as well as various blanching times, in order to minimize quality factors losses and browning incidence in subsequent stages of product processing and storage. Sprouts were firstly treated for 5 min, either in water at 50 ┐ C or by microwaves, and then blanched in boiling water for 3 or 2 min, respectively. Other samples were directly blanched by immersion in water (100 ┐ C) for 1, 3 or 4 min. Thermal history, surface colour, texture, total chlorophyll, radical scavenging activity, ascorbic acid and total flavonoids content were determined. Microwaves pre-blanching showed no deleterious effects on total chlorophyll, radical scavenging activity, total flavonoids and ascorbic acid content of Brussels sprouts and the moderate heat treatment induced by this method may be considered to be a useful tool to improve health properties of Brussels sprouts.

Wennberg, M., Engqvist, G. & Nyman, M. (2002). Effects of harvest time and storage on dietary fibre components in various cultivars of white cabbage (Brassica oleracea var capitata). *Journal of the Science of Food and Agriculture*, 82 (12), 1405-1411.

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The effect of harvest time and storage on dietary fibre content and composition was investigated in six cultivars of white cabbage. Three cultivars were of early maturity type (SW Nordpol, Rolly and Balbro) and three of late maturity type (Predikant, Hanna and Lion). The average total dietary fibre (TDF) content was 241 g/kg dry matter, of which approximately 25% was soluble. The main dietary fibre components were glucose (37%), uronic acid (32%), arabinose (12%) and galactose (8%) residues.

Storage for 6 weeks had minor effects on the dietary fibre. After further storage of the late maturity cultivars, there was an increase in insoluble dietary fibre (IDF) (glucose and uronic acid residues) and a decrease in SDF (arabinose and galactose residues). As a consequence the solubility of TDF decreased from 29 to 19% on average. Long-term storage had fewer effects on cabbage harvested prior to maturity than when harvested at the right physiological maturity. It is concluded that the observed differences between cultivars and after long term storage are of such magnitude that they may affect nutritional properties of the dietary fibre.

Winkler, S.; Faragher, J.; Franz, P.; Imsic, M.; Jones, R. (2007). Glucoraphanin and flavonoid levels remain stable during simulated transport and marketing of broccoli (Brassica oleracea var. italica) heads. Postharvest Biology and Technology, 43, 89–94

Fresh broccoli heads contain relatively high levels of beneficial phytochemicals, particularly glucosinolates and flavonoids, but it is not clear whether or not the levels are affected by postharvest handling conditions. Accordingly, broccoli heads (Brassica oleracea var. italica) were stored at temperatures of 1 or 4 ◦C, 99% relative humidity (RH), for 2, 7, 14 or 28 days to simulate domestic and export transport conditions. After removal from cool storage, heads were then placed at 8, 15 or 20 ◦C, with 99, 90 or 70% RH, respectively, for 3 days to simulate marketing conditions. At the end of both phases, heads were rated for visual quality, turgor, presence of rots and yellowing, and the contents of glucoraphanin, quercetin and kaempferol were measured. Visual quality declined significantly with increasing temperature and length of storage, caused primarily by increasing yellowing and loss of turgor. Glucoraphanin, quercetin and kaempferol contents were not significantly affected by storage and marketing temperature and time. These results suggest that current transport and marketing practices are not likely to have a deleterious effect on the levels of aliphatic glucosinolates and flavonols in broccoli.

Yamaguchi, T., Katsuda, M., Oda, Y., Terao, J., Kanazawa, K., Oshima, S., Inakuma, T., Ishiguro, Y., Takamura, H. and Matoba, T. (2003). Influence of polyphenol and ascorbate oxidases during cooking process on the radical-scavenging activity of vegetables. *Food Science and Technology Research*, 9, 79-83.

The study investigated the radical scavenging activity, total phenol content and ascorbic acid content of broccoli during processing using a freeze-dried vegetable powder before and after heating.

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The freeze-dried vegetable powder was added to 2 ml of water, capped and stirred by shaker for 1, 5, 10 and 15 min to simulate the cooking process. To determine the influence of heating, the freeze-dried vegetable powder was added to 2 ml of boiling water and heated in a water bath for 10 min.
The radical-scavenging activity of heated broccoli remained constant during the 15 min processing period, while the radical-scavenging activity of non-heated broccoli decreased gradually during processing and remained at about 6% after 15 min. The phenol content of heated and non-heated broccoli remained constant after 15 min of processing. The remaining percentage of ascorbic acid in unheated broccoli was 34, 11 and 5 % after 1, 5 and 10 min respectively and none was left after 15 min. The amount of ascorbic acid in heated broccoli remained close to 100% during processing.

Zhang, D. And Hamauzu, Y. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chemistry*, 88, 503-509.
The objective of this study was to investigate phenolics, ascorbic acid and carotenoids, total antioxidant activity and antioxidant activity of phenolic extracts (measured by DPPH method) of broccoli floret and stem and their changes during conventional and microwave cooking.
10 g of broccoli were added to 200 ml of water and conventionally cooked and cooked in a domestic microwave oven (600W) for 30, 60, 90, 120 and 300s.
Fresh broccoli floret contained 7.7 times more phenolics than the stem. The florets cooked conventionally for 30, 60, 90, 120 and 300 s lost 31.6%, 47.5%, 55.9%, 61.7% and 71.9% of total phenolics present in the fresh floret, respectively. In the microwave cooking, the change in total phenolics in both florets and stems showed a similar trend. Fresh broccoli stem contained 19.8% more ascorbic acid than the floret. The florets cooked conventionally for 30, 60, 90, 120 and 300 s lost 19.2%, 33.5%, 47.5%, 59.2% and 65.9% of ascorbic acid present in the fresh florets, respectively, while the cooked stems lost 19.1%, 33.4%, 47.7%, 59.2% and 70.9% respectively. In the microwave cooking (for 300s) the florets and stems lost 65.6% and 70.5% respectively of ascorbic acid. The stem contained less than 3% of total carotenoids present in the floret. Both conventional and microwave cooking caused loss of total carotenoids in broccoli florets and stems. The florets cooked conventionally for 30, 60, 90, 120 and 300s lost 2.7%, 12%, 14.4%, 17.1% and 22.9% of total carotenoids, respectively, while the stems cooked fro 60, 120 and 300s lost 10%, 20% and 20% respectively. In the microwave cooking, total carotenoids in the florets and stems also declined continuously. The florets cooked in microwave for 120 and 300 s lost 17.3% and 22.7% of total carotenoids, respectively, while the cooked stem lost 20%. The level of β-carotene declined during the conventional and microwave cooking, 76.2% of β-carotene was lost in the first 60s. On the other hand, the level of lutein increased gradually during the conventional and microwave cooking. The level increased by 26.7% during the cooking for 300 s. Broccoli floret and stem extracts were found to possess good antioxidant activity. Phenolic extract accounted for 20% and 2.7% of total antioxidant activity in the floret and stems, respectively. Total antioxidant activity and

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phenolic antioxidant activity of broccoli florets and stems declined during the conventional and microwave cooking. During the conventional cooking, the florets retained 80.8%, 66.4%, 54.2%, 39.2% and 35% of total antioxidant activity after being cooked for 30, 60, 90, 120 and 300 s respectively, while the stems retained 88.2%, 76.5%, 70.6%, 70.6% and 64.7% respectively. In the microwave cooking, the changes of antioxidant activity showed a similar trend. The florets and stems after microwave cooking for 300 s, retained 34.7% and 34.6% of total antioxidant activity and 37.2% and 64.7% of phenolic antioxidant activity, respectively.

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5. ATTACHMENTS – TABLES VEGETABLES

5.1 Broccoli *(Brassica oleracea var. italica)*

5.2 Cabbage *(Brassica oleracea var. capitata)*

5.3 Carrot *(Daucus carota)*

5.4 Cauliflower *(Brassica oleracea var. botrytis)*

5.5 Green bean *(Phaseolus vulgaris)*

5.6 Green pea *(Pisum sativum)*

5.7 Onion *(Allium cepa)*

5.8 Spinach *(Spinacia oleracea)*

5.9 Bell pepper (Capsicuum annuum)

5.10. Brussels sprouts *(Brassica oleracea var. gemmifera)*

5.11. Other vegetables

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6. REFERENCE LIST FRUITS

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Agostini, L.R., Jimenez, M.J.M., Ramon, A.N. & Gomez, A.A. (2004). Determinacion de la capacidad antioxidante de flavonoides en frutas y verduras frescas y tratadas termicamente. *Archivos Latinoamericanos de Nutricion*, **54**, 89-92.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry*, **52**(1), 1237-1241.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003b). Processing-induced changes in total phenolics and procyanidins in clingstone peaches. *Journal of the Science of Food and Agriculture*, **83**(1), 56-63.

Ayala-Zavala, J.F., Wang, S.Y., Wang, C.Y. & Gonzalez-Aguilar, G.A. (2004). Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. *Lebensmittel-Wissenschaft und-Technologie*, **37**(7), 687-695.

Ayranci, E. & Tunc, S. (2004). The effect of edible coatings on water and vitamin C loss of apricots (Armeniaca vulgaris Lam.) and green peppers (Capsicum annuum L.). *Food Chemistry*, **87**(3), 339-342.

Böhm, V., Kühnert, S., Rohm, H. & Scholze, G. (2006). Improving the nutritional quality of microwave-vacuum dried strawberries: a preliminary study. *Food Science and Technology International*, **12**(1), 67-75.

Chaovanalikit, A. & Wrolstad, R.E. (2004). Anthocyanin and polyphenolic composition of fresh and processed cherries. *Journal of Food Science*, **69**(1), C73-83.

Chaovanalikit, A. & Wrolstad, R.E. (2004b). Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. *Journal of Food Science*, **69**(1), C67-72.

Cordenunsi, B.R., Genovese, M.I., do Nascimento, J.R.O., Hassimotto, N.M.A., dos Santos, R.J. & Lajolo, F.M. (2005). Effects of temperature on the chemical composition and antioxidant activity of three strawberry cultivars. *Food Chemistry*, **91**(1), 113-121.

Cordenunsi, B.R., Nascimento, J.R.O. & Lajolo, F.M. (2003). Physico-chemical changes related to quality of five strawberry fruit cultivars during cool-storage. *Food Chemistry*, **83**(2), 167-173.

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Esti, M., Cinquanta, L., Sinesio, F., Moneta, E. & Di Matteo, M. (2002). Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage. *Food Chemistry*, **76**(4), 399-405.

Galvis-Sanchez, A.C., Fonseca, S.C., Gil-Izquierdo, A., Gil, M.I. & Malcata, F.X. (2006). Effect of different levels of CO2 on the antioxidant content and the polyphenol oxidase activity of 'Rocha' pears during cold storage. *Journal of the Science of Food and Agriculture, **86**(4), 509-517.*

Gil, M.I., Aguayo, E. & Kader, A.A. (2006). Quality changes and nutrient retention in fresh-cut versus whole fruits during storage. *Journal of Agricultural and Food Chemistry*, 54(12), 4284-4296.

Gonçalves, B., Landbo, A.K., Let, M., Silva, A.P., Rosa, E. & Meyer, A.S. (2004). Effect of ripeness and storage on the phenolic profiles of cherries (Prunus avium L.). *Journal of Agricultural and Food Chemistry*, **52**(3), 523-530.

Gonçalves, B., Landbo, A.K., Let, M., Silva, A.P., Rosa, E. & Meyer, A.S. (2004b). Storage affects the phenolic profiles and antioxidant activities of cherries (Prunus avium L) on human low-density lipoproteins. *Journal of the Science of Food and Agriculture*, **84**(9), 1013-1020.

Haffner, K., Rosenfeld, H.J., Skrede, G. & Wang, L.X. (2002). Quality of red raspberry Rubus idaeus L. cultivars after storage in controlled and normal atmospheres. *Postharvest Biology and Technology*, **24**(3), 279-289.

Han, C., Zhao, Y., Leonard, S.W. & Traber, M.G. (2004). Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (Fragaria x ananassa) and raspberries (Rubus ideaus). *Postharvest Biology and Technology*, **33**(1), 67-78.

Jiang, A.-L., Tian, S.-P. & Xu, Y. (2002). Effects of controlled atmosphere with high-O_2 or high-CO_2 concentrations on postharvest physiology and storability of "Napoleon" sweet cherry. *Acta Botanica Sinica*, **44**(8), 925-930.

Kalt, W. (2005). Effects of production and processing factors on major fruit and vegetable antioxidants. *Journal of Food Science*, **70**(1), R11-19.

Karatas, F. & Kamish, F. (2007). Variation of vitamins (A, C and E) and MDA in apricots dried in IR and microwave. Journal of Food Engineering, 78, 662-668.

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Kim, D.-O. & Padilla-Zakour, O.I. (2004). Jam processing effect on phenolics and antioxidant capacity in anthocyanin-rich fruits: cherry, plum, and raspberry. *Journal of Food Science,* **69**(9), S395-400.

Klimczak, I., Maleka, M., Szlachta, M. Gliszczynska—Swiglo, A. (2007). Effect on storage on the content of polyphenols, vitamine C and the antioxidant activity of orange juices

Koyuncu, M.A. (2004). Quality changes of three strawberry cultivars during the cold storage. *European Journal of Horticultural Science*, **69**(5), 193-200.

Leja, M., Mareczek, A. & Ben, J. (2003). Antioxidant properties of two apple cultivars during long-term storage. *Food Chemistry*, **80**(3), 303-307.

Maclean, D.D., Murr, D.P., DeEll, J.R. & Horvath, C.R. (2006). Postharvest variation in apple (Malus x domestica Borkh.) flavonoids following harvest, storage and 1-MCP treatment. *Journal of Agricultural and Food Chemistry*, **54**(3), 870-878.

Mozetic, B., Simcic, M. & Trebse, P. (2006). Anthocyanins and hydroxycinnamic acids of Lambert Compact cherries (Prunus avium L.) after cold storage and 1-methylcyclopropene treatment. *Food Chemistry*, **97**(2), 302-309.

Mullen, W., Stewart, A.J., Lean, M.E.J., Gardner, P., Duthie, G.D. & Crozier, A. (2002). Effect of freezing and storage on the phenolics, ellagitannins, flavonoids, and antioxidant capacity of red raspberries. *Journal of Agricultural and Food Chemistry*, **50**(18), 5197-5201.

Napolitano, A., Cascone, A., Graziani, G., Ferracane, R., Scalfi, L., Di Vaio, C., Ritieni, A. & Fogliano, V. (2004). Influence of variety and storage on the polyphenol composition of apple flesh. *Journal of Agricultural and Food Chemistry*, **52**(21), 6526-6531.

Nunes, M.C.N., Brecht, J.K., Morais, A.M.M.B. & Sargent, S.A. (2005). Possible influences of water loss and polyphenol oxidase activity on anthocyanin content and discoloration in fresh ripe strawberry (cv. Oso Grande) during storage at 1°C. *Journal of Food Science*, **70**(1), S90-95.

Olsson, M.E., Ekvall, J., Gustavsonn, K.E., Nilsson, J., Pillai, D. Sjöholm, Svensson, Åkesson, B. & Nyman, M.G.L. (2004). Antioxidants, low molecular weight carbohydrates and total antioxidant capacity in strawberries (Frangaria x ananassa): effects of cultivar, ripening and storage. *Journal of Agricultural and Food Chemistry*, **52**(9), 2490-2498.

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Pan, J., Vicente, A.R., Martinez, G.A., Chaves, A.R. & Civello, P.M. (2004). Combined use of UV-C irradiation and heat treatment to improve postharvest life of strawberry fruit. *Journal of the Science of Food and Agriculture*, **84**(14), 1831-1838.

Rababah, T.M., Ereifej, K.I. & Howard, L. (2005). Effect of ascorbic acid and dehydration on concentrations of total phenolics, antioxidant capacity, anthocyanins and color in fruits. *Journal of Agricultural and Food Chemistry*, **53**(11), 4444-4447.

Sahari, M.A., Boostani, F.M. & Hamidi, E.Z. (2004). Effect of low temperature on the ascorbic acid content and quality characteristics of frozen strawberry. *Food Chemistry*, **86**(3), 357-363.

Sousa, M.B., Canet, W., Alvarez, M.D. & Tortosa, M.E. (2005). The effect of the pre-treatments and the long and short-term frozen storage on the quality of raspberry (cv. *Heritage*). *European Food Research and Technology*, **221**(1-2), 132-144.

Strålsjö, L.M., Witthöft, C.M., Sjöholm, I.M. & Jägerstad, M.I. (2003). Folate content in strawberries (Fragaria x ananassa): effects of cultivar, ripeness, year of harvest, storage, and commercial processing. *Journal of Agricultural and Food Chemistry*, **51**(1), 128-133.

Suthanthangjai, W., Kajda, P. & Zabetakis, L. (2005). The effect of high hydrostatic pressure on the anthocyanins of raspberry (Rubus idaeus). *Food Chemistry*, **90**(1-2), 193-197.

Suutarinen, J., Honkapää, K., Heiniö, R.-L., Autio, K., Mustranta, A., Karppinen, S., Kiutamo, T., Liukkonen-Lilja, H. & Mokkila, M. (2002). Effects of calcium chloride-based prefreezing treatments on the quality factors of strawberry jams. *Journal of Food Science*, **67**(2), 884-894.

Trierweiler, B., Krieg, M. & Tauscher, B. (2004). Antioxidative capacity of different apple cultivars after long-time storage. *Journal of Applied Botany and Food Quality*, **78**(2), 117-119.

Vicente, A.R., Martinez, G.A., Civello, P.M. & Chaves, A.R. (2002). Quality of heat-treated strawberry fruit during refrigerated storage. *Postharvest Biology and Technology*, **25**(1), 59-71.

Wicklund, T., Rosenfeld, H.J., Martinsen, B.K., Sundfor, M.W., Lea, P., Bruun, T., Blomhoff, R. & Haffner, K. (2005). Antioxidant capacity and colour of strawberry jam as influenced by cultivar and storage conditions. *Lebensmittel-Wissenschaft und-Technologie*, **38**(4), 387-391.

Yaman, O. & Bayoindirli, L. (2002). Effects of an edible coating and cold storage on shelf-life and quality of cherries. *Lebensmittel-Wissenschaft und-Technologie*, **35**(2), 146-150.

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Zuo, L., Lee, E.J. & Lee, J.H. (2004). Effect of hot water treatment on quality of fresh-cut apple cubes. *Food Science and Biotechnology*, **13**(6), 821-825.

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7. SUMMARIES FRUITS

Agostini, L.R., Jimenez, M.J.M., Ramon, A.N. & Gomez, A.A. (2004). Determinacion de la capacidad antioxidante de flavonoides en frutas y verduras frescas y tratadas termicamente. *Archivos Latinoamericanos de Nutricion*, 54, 89-92.

Retention of antioxidant capacity of apples, measured as µM Trolox Equivalent, was found to be 91.5, 86.1, 66.4 and 49.4% after boiling, steam cooking, microwaving and drying, respectively. For strawberries 81.3, 82.0, 49.6 and 27.7% of the antioxidant capacity was retained after boiling, steam cooking, microwaving and drying, respectively.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry*, 52(1), 1237-1241.

The impact of freeze-drying and air-drying on ascorbic acid (AA) was compared to those in fresh samples that were frozen and stored at -12°C. Levels of total phenolics (TPs) in air-dried and freeze-dried were compared to those found in frozen samples because the fresh samples were not available for analysis. Sustainable grown and frozen strawberries contained higher levels (20.3%) of AA as compared to conventionally grown strawberries. The average AA levels in sustainable grown and freeze-dried or air-dried fruit were significantly lower ($p<0.05$) at 44.2 and 16.2% of levels in frozen strawberries. The only marrionberry samples found to contain detectable levels of AA were the sustainable grown and frozen berries, which had 2.9mg of AA/100 g of fresh weight. The TP levels in air-dried marionberries were 15.6-21.1% lower than those found in frozen fruit. Differences in TP levels between freeze-dried and frozen marionberries were not significant. TP levels in freeze-dried and air-dried strawberries were 31.5-42.6% lower than those of frozen strawberries. There was no statistical difference ($p<0.05$) in TP levels between air-dried and freeze-dried samples.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003b). Processing-induced changes in total phenolics and procyanidins in clingstone peaches. *Journal of the Science of Food and Agriculture*, 83(1), 56-63.

Maturity class MIII peaches were stored at three different temperatures for different periods of time. One group of peaches was frozen at -12°C for 0, 1, 2 and 3 months to simulate frozen storage for analytical purposes. Another group was stored under refrigeration (4°C) conditions for 0, 7 and 14 days to mimic storage at the processor site prior to processing. A third group was stored at 30°C for 0, 12, 24 and 48 hours to simulate fruit waiting in bins in a receiving yard prior to processing. Levels of phenolics of unprocessed peaches were 326 +/- 8.5 mg/kg for peeled fruit and 376+/-25.8 mg/kg for unpeeled fruit. On average, unpeeled fruit contained 1.5-fold higher levels of phenolics than peeled fruit. Manual peeling results in a 1.3-fold higher retention of total phenolics than lye assisted

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peeling. Storage of peeled peaches at -12°C results in a statistically significant increase in total phenolics, as compared with fresh peach, over a period of 3 months. Cold storage of peaches for 4 days resulted in no loss in total phenolic activity in either the peeled or unpeeled peaches. Storage of peaches for 24h at 30°C resulted in a 69% increase in total phenolics in peeled fruit and a 36% increase in unpeeled fruit. Thermal processing of peaches at 220°F for 10min resulted in a 21% loss in total phenolics, a temperature of 230°F for 2.4min resulted in an 11% loss in total phenolics, whereas a temperature of 213°F for 40min produced no significant loss in total phenolics as compared to raw material. Storing canned peaches at room temperature during the first 3 month period results in a 30-40% loss in total phenolics in all samples.

Ayala-Zavala, J.F., Wang, S.Y., Wang, C.Y. & Gonzalez-Aguilar, G.A. (2004). Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. *Lebensmittel-Wissenschaft und-Technologie*, 37(7), 687-695.

Strawberry fruit stored at 10°C or 5°C showed higher antioxidant capacity, total phenolics and anthocyanins than those stored at 0°C. Anthocyanin content in fruit stored at 10°C increased gradually and reached the highest values near the end of the storage period (+ about 7.5% in 10 days). Strawberry fruit stored at 0°C and 5°C showed a decease in anthocyanin content during the first 5 days (about 7.5% and 6% respectively). The total phenolics increased continuously in berries stored at 10°C (+57%) and 5°C (+ 30%). At 0°C the strawberries maintained a constant value of total phenolics during the storage period (13 days). The antioxidant capacity of strawberries at 0°C changed very little, at 5°C and 10°C significant increases were found (about 37% and 83% respectively).

Ayranci, E. & Tunc, S. (2004). The effect of edible coatings on water and vitamin C loss of apricots (Armeniaca vulgaris Lam.) and green peppers (Capsicum annuum L.). *Food Chemistry*, 87(3), 339-342.

Edible coatings of varying composition were applied on fresh apricots. The vitamin C content was compared with those of non-coated products. Coated and uncoated products were kept at 25°C and 84% relative humidity. After 12 days of storage the non-coated apricots showed a 78% loss in vitamin C content. In the coated apricots this loss varied between 74 and 37%.

Böhm, V., Kühnert, S., Rohm, H. & Scholze, G. (2006). Improving the nutritional quality of microwave-vacuum dried strawberries: a preliminary study. *Food Science and Technology International*, 12(1), 67-75.

Convective drying and microwave-vacuum drying decreased the content of ascorbic acid to 40% of the initial value, phenolic compounds to 35% and the antioxidative capacity to 60%. No reduction was observed in freeze-dried strawberries. By-passing the pre-treatment bath, extending residence time in the pre-dryer to reduce temperature peaks and reducing microwave-vacuum treatment time

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increased the recovery of ascorbic acid to 65%. Phenolic compounds remained stable and the reduction of antioxidant capacity was limited to 10-25%.

Chaovanalikit, A. & Wrolstad, R.E. (2004). Anthocyanin and polyphenolic composition of fresh and processed cherries. *Journal of Food Science*, 69(1), C73-83.

Chaovanalikit, A. & Wrolstad, R.E. (2004b). Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. *Journal of Food Science*, 69(1), C67-72.

The effects of freezing and canning of cherries on their anthocyanin and phenolic content was investigated. During frozen storage at -23°C, the level of anthocyanins and total phenolics respectively decreased by 66% and 25% after 3 months and by 87% and 50% after 6 months. When stored at -70°C, the loss of anthocyanins was found to be 10% and 12% after 3 and 6 months respectively, while the level of phenolics was actually found to increase by 8% after 3 months and 3% after 6 months. The heat treatment applied during canning did not affect the anthocyanin content and even resulted in a 20% increase in phenolic content of cherries. However, subsequent storage resulted in a loss in total anthocyanin content of 11% after 5 months at 2°C and of 38% after 5 months at 22°C, although the anthocyanins became evenly distributed between cherries and syrup. The total phenolic content actually showed an increase upon storage: 21% at 2°C and 19% at 22°C.

Cordenunsi, B.R., Genovese, M.I., do Nascimento, J.R.O., Hassimotto, N.M.A., dos Santos, R.J. & Lajolo, F.M. (2005). Effects of temperature on the chemical composition and antioxidant activity of three strawberry cultivars. *Food Chemistry*, 91(1), 113-121.

Strawberries were harvested at the ripe stage and stored at 6, 16 and 25°C for 5 days. The strawberries accumulated anthocyanins during storage (+/- 200% increase). All the strawberries presented lower amounts of anthocyanin when stored at 6°C compared to higher storage temperatures. One cultivar was mostly affected since the final amount was only 30% of that for fruits stored at room temperature. Storage at 16°C kept the pigment content at levels similar to that of the control fruit. The amount of flavonols did not increase with storage at the temperatures tested. The strawberries presented a total phenolics content of around 300mg/100g FW which was not altered by storage. For strawberries stored at 16°C, an increase of at least 16% in ascorbic acid content was detected at the end of storage. Storage at 6°C was an effective way to maintain the initial levels of total ascorbic acid for several days, but did not lead to a significant increase. Antioxidant activities decreased upon storage from 9 to 30%.

Cordenunsi, B.R., Nascimento, J.R.O. & Lajolo, F.M. (2003). Physico-chemical changes related to quality of five strawberry fruit cultivars during cool-storage. *Food Chemistry*, 83(2), 167-173.

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Strawberry cultivars were harvested at the ripe stage and stored at 6°C for 6 days. Changes in anthocyanin content were highly dependent on the cultivar, ranging from a 20% increase to a 27% decrease. Ascorbic acid decreased by 50% in all cultivars.

Esti, M., Cinquanta, L., Sinesio, F., Moneta, E. & Di Matteo, M. (2002). Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage. *Food Chemistry*, 76(4), 399-405.

All cultivars showed a decrease in total anthocyanins of 52%-41% after 15 days of storage at 1°C and 95% relative humidity.

Galvis-Sanchez, A.C., Fonseca, S.C., Gil-Izquierdo, A., Gil, M.I. & Malcata, F.X. (2006). Effect of different levels of CO2 on the antioxidant content and the polyphenol oxidase activity of 'Rocha' pears during cold storage. *Journal of the Science of Food and Agriculture, 86(4), 509-517.*

Ascorbic acid was measured in the flesh and the peel of pears after harvest, followed by 1, 6, 9 and 14 days in air at room temperature (18-20°C). At the end of the storage period, the ascorbic acid in the flesh had decreased by 77% while in the peel this decrease was only 53%. After four months of storage in air, the pears were kept at room temperature for 8 days. During these extra 8 days the ascorbic acid content in the flesh decreased an extra 25%.

Gil, M.I., Aguayo, E. & Kader, A.A. (2006). Quality changes and nutrient retention in fresh-cut versus whole fruits during storage. *Journal of Agricultural and Food Chemistry*, 54(12), 4284-4296.

The influences of processing and storage on the quality indices and nutritional content of fresh-cut fruits were evaluated in comparison to whole fruits stored for the same duration but prepared on the day of sampling. Fresh-cut pineapples, mangoes, cantaloupes, watermelons, **strawberries**, and kiwifruits and whole fruits were stored for up to 9 days in air at 5 degrees C. The postcutting life based on visual appearance was shorter than 6 days for fresh-cut kiwifruit and shorter than 9 days for fresh-cut pineapple, cantaloupe, and **strawberry**. On the other hand, fresh-cut watermelon and mango pieces were still marketable after 9 days at 5 degrees C. Losses in vitamin C after 6 days at 5 degrees C were <= 5% in mango, **strawberry**, and watermelon pieces, 10% in pineapple pieces, 12% in kiwifruit slices, and 25% in cantaloupe cubes. No losses in **carotenoids** were found in kiwifruit slices and watermelon cubes, whereas losses in pineapples were the highest at 25% followed by 10-15% in cantaloupe, mango, and **strawberry** pieces after 6 days at 5 degrees C. No significant losses in total phenolics were found in any of the fresh-cut fruit products tested after 6 days at 5 degrees C. Light exposure promoted browning in pineapple pieces and decreased vitamin C content in kiwifruit slices. Total **carotenoids** contents decreased in cantaloupe cubes and kiwifruit slices, but increased in mango and watermelon cubes in response to light exposure during storage

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at 5 degrees C for up to 9 days. There was no effect of exposure to light on the content of phenolics. In general, fresh-cut fruits visually spoil before any significant nutrient loss occurs.

Gonçalves, B., Landbo, A.K., Let, M., Silva, A.P., Rosa, E. & Meyer, A.S. (2004). Effect of ripeness and storage on the phenolic profiles of cherries (Prunus avium L.). ***Journal of Agricultural and Food Chemistry*****, 52(3), 523-530.**

Ripe cherries were stored at room temperature (15°C+/- 5°C) and at 1-2°C (cold storage). After 6 days at room temperature, an increase in total phenolics could be noted (45-99%). After 30 days of cold storage the total phenolic content increased by 6-43%.The anthocyanin content increased both during room temperature storage and cold storage (102-387% and 131-240% respectively). The total flavonol + flavan-3-ols increased 45%-82% during storage at room temperature and 3%-23% during cold storage.

Gonçalves, B., Landbo, A.K., Let, M., Silva, A.P., Rosa, E. & Meyer, A.S. (2004b). Storage affects the phenolic profiles and antioxidant activities of cherries (Prunus avium L) on human low-density lipoproteins. ***Journal of the Science of Food and Agriculture*****, 84(9), 1013-1020.**

Sweet cherries were analysed at harvest and after storage at 2°C and 15°C for 30 and 6 days respectively. During storage at 15°C the observed changes in total phenolics ranged from a 16% decrease to a 34% increase, depending on the cultivar. For cold storage, changes ranged from a 20% decrease to a 37% increase. The antioxidant activity decreased with 51-85% during storage for 6 days at 15°C and with 9-96% during storage for 30 days at 2°C.

Haffner, K., Rosenfeld, H.J., Skrede, G. & Wang, L.X. (2002). Quality of red raspberry Rubus idaeus L. cultivars after storage in controlled and normal atmospheres. ***Postharvest Biology and Technology*****, 24(3), 279-289.**

The vitamin C content at harvest decreased by about 10% during 9 days in controlled atmosphere or at 1°C.

Han, C., Zhao, Y., Leonard, S.W. & Traber, M.G. (2004). Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (Fragaria x ananassa) and raspberries (Rubus ideaus). ***Postharvest Biology and Technology*****, 33(1), 67-78.**

Chitosan-based edible coatings were used to extend the shelf-life and enhance the nutritional value of strawberries and red raspberries stored either at 2°C and 88% relative humidity for 3 weeks or at 23°C up to 6 months. One hundred grams of coated fruit contained about 34-59 mg of calcium, or 1.7-7.7 mg of vitamin E depending on the type of fruit and the time of storage, while uncoated fruits contained only 19-21 mg of calcium or 0.25-1.15 mg of vitamin E. Coatings increased the vitamin E content for one serving of fresh strawberries (200g) from 4.6-6.6% to 22.7-39.9 DRI in uncoated samples. The calcium content increased to 6.8-7.3% DRI in fresh strawberries. Storage did not

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significantly (p>0.05) decrease the vitamin E content of coated fruit, although trended down, while uncoated berries lost about from 22 to 59% of their initial α-tocopherol. One week of cold storage up to 6 months of frozen storage did not cause significant loss of vitamin E, but the vitamin E content dropped about 15-17% by the end of two weeks cold storage.

Jiang, A.-L., Tian, S.-P. & Xu, Y. (2002). Effects of controlled atmosphere with high-O_2 or high-CO_2 concentrations on postharvest physiology and storability of "Napoleon" sweet cherry. *Acta Botanica Sinica*, 44(8), 925-930.

The vitamin C content of cherries decreased with 75% during storage for 60 days at 1°C.

Kalt, W. (2005). Effects of production and processing factors on major fruit and vegetable antioxidants. *Journal of Food Science*, 70(1), R11-19.

Strawberries stored at 20°C lost between 55% and 70% of their ascorbic acid after only 4 days. The ascorbic acid content of 3 apple varieties showed a 25-30% decrease after 6 months of conventional storage. Apples stored at 1.5°C and 4°C retained their flavonoid phenolics throughout their storage life. In another study, apples stored at 5°C lost 25.7% of their total phenolic content after about 6 months.

Karatas, F. & Kamish, F. (2007). Variation of vitamins (A, C and E) and MDA in apricots dried in IR and microwave. Journal of Food Engineering, 78, 662-668.

In this study, variations of vitamins (A, C and E) and malondialdehyde (MDA) with moisture removals were investigated in apricot samples in different ripeness namely ''near-ripe'' and ''ripe'' apricots that were dried in infrared and microwaves driers. For two drying systems, the values of vitamins (A and E) and MDA in the ripe apricot were observed to be higher than those in the near-ripe apricot samples at all moisture removals. The values of vitamins (A, C and E) and MDA in apricot samples dried in the microwave drier were found to be larger than those in apricot samples dried in infrared. Infrared and microwave driers were compared one another in terms of less losses of vitamins and MDA, rate of drying and preservation of original color of apricot. It was concluded that microwave drier is more effective than IR drier in terms of less losses of vitamins, rate of drying and preservation of original color of apricots.

Kim, D.-O. & Padilla-Zakour, O.I. (2004). Jam processing effect on phenolics and antioxidant capacity in anthocyanin-rich fruits: cherry, plum, and raspberry. *Journal of Food Science,* 69(9), S395-400.

The change in phenolic and anthocyanin content of different fruits as a consequence of jam making was investigated. For different cherry varieties, jam making resulted on average in a 46% decrease in total phenolics and a 86% decrease in total anthocyanins. For plums, a 51% and 79% loss was

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observed in total phenolics and total anthocyanins respectively. The phenolic and anthocyanin level of raspberries was found to decrease with 36% and 45% respectively.

Klimczak, I., Maleka, M., Szlachta, M. Gliszczynska—Swiglo, A. (2007). Effect on storage on the content of polyphenols, vitamine C and the antioxidant activity of orange juices

The effect of time and temperature on the content of vitamin C, total polyphenols and individual phenolic compounds as well as on the antioxidant activity of two commercial orange juices was studied. The polyphenol content was determined using Folin–Ciocalteu and HPLC methods. The two methods, SPE versus direct injection following a simple treatment of samples, were compared to assess two techniques of sample preparation. For antioxidant capacity determination, DPPH and FRAP assays were used. All analyses were carried out for fresh juices and after storage at 18, 28 and 38 1C for 2, 4 and 6 months. It was found that vitamin C and free and conjugated hydroxycinnamic acids were the most affected by both duration and temperature of storage. The decrease in the content of polyphenols and vitamin C upon storage was reflected by the decrease in the antioxidant capacity of orange juices. Small changes in flavanone content
were observed, indicating high stability of these compounds upon storage.

Koyuncu, M.A. (2004). Quality changes of three strawberry cultivars during the cold storage. *European Journal of Horticultural Science*, 69(5), 193-200.

Changes in vitamin C content upon storage at 0°C and 90-95% relative humidity were determined for three strawberry cultivars. Two cultivars did not show a significant vitamin C decrease after 10 days of storage, while a 44% loss was found for the third one.

Leja, M., Mareczek, A. & Ben, J. (2003). Antioxidant properties of two apple cultivars during long-term storage. *Food Chemistry*, 80(3), 303-307.

Apples were stored 120 days at 0°C under regular storage conditions (85-90% RH). The fruit peel was analyzed just after harvesting, after cold storage, followed by 1 day storage at 16°C and after an additional 7 days at 16°C. After cold storage, the total antioxidant activity increased with 49-155% compared to day zero. After an additional period of 7 days at 16°C, this increase was 120-140% compared to day zero. The anthocyanin level decreased with 14-25% and 20-28% respectively. The total phenols increased during cold storage with 0-15% compared to day zero. After an additional period of 7 days at 16°C a 23-40% increase compared to day zero was noticed.

Maclean, D.D., Murr, D.P., DeEll, J.R. & Horvath, C.R. (2006). Postharvest variation in apple (Malus x domestica Borkh.) flavonoids following harvest, storage and 1-MCP treatment. *Journal of Agricultural and Food Chemistry*, 54(3), 870-878.

The level of flavonoids during cold storage did not consistently change. In general, the levels of flavonoids remained near harvest levels over the course of the 10 days of cold storage. The

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anthocyanins decreased 8.7% during 120 days of cold storage (0-1°C). The major decrease took place during the first 60 days.

Mozetic, B., Simcic, M. & Trebse, P. (2006). Anthocyanins and hydroxycinnamic acids of Lambert Compact cherries (Prunus avium L.) after cold storage and 1-methylcyclopropene treatment. *Food Chemistry*, 97(2), 302-309.
After 12 days of storage at 2-4°C, the control group showed no change in anthocyanin content.

Mullen, W., Stewart, A.J., Lean, M.E.J., Gardner, P., Duthie, G.D. & Crozier, A. (2002). Effect of freezing and storage on the phenolics, ellagitannins, flavonoids, and antioxidant capacity of red raspberries. *Journal of Agricultural and Food Chemistry*, 50(18), 5197-5201.
Ripe field-grown raspberries were divided in four lots: (1) fresh, (2) frozen: frozen within 3h of picking at -30°C, (3) store: 3 days at 4°C prior to freezing in liquid nitrogen, (4) home :3 days at 4°C followed by 24h at 18°C prior to freezing in liquid nitrogen. The antioxidative capacity of the fresh fruit and the levels of vitamin C and phenolics were not affected by freezing. The levels of total phenolics were significantly higher in the shop (3510 +/- 107 nmol/g) and home (3769 +/- 125 nmol/g) raspberries than in the fresh (3383 +/- 230 nmol/g) and frozen food: The low levels of ellagic acid rose during storage (fresh: 3.5 +/- 0.1 nmol/g; frozen: 3.9 +/- 0.1 nmol/g; shop: 6.4 +/- 0.1 nmol/g; home: 18.5 +/- 0.2 nmol/g). Under “shop” and “home” conditions the vitamin C levels declined compared to fresh and frozen berries. Overall there was no effect on the antioxidative capacity of the fruit.

Napolitano, A., Cascone, A., Graziani, G., Ferracane, R., Scalfi, L., Di Vaio, C., Ritieni, A. & Fogliano, V. (2004). Influence of variety and storage on the polyphenol composition of apple flesh. *Journal of Agricultural and Food Chemistry*, 52(21), 6526-6531.
Ripe apples were stored up to 4 months in conditions usually adopted for marketing by means of cold storage at 2°C. At the end of cold storage, a decrease of 27.5 to 47.3% was detected for antioxidant activity. For the total phenolics the influence of storage was strongly dependent on the cultivar: 2 cultivars showed an increase (11% and 26%) while two others showed a decrease (-91% and -1.5%) in total phenolics.

Nunes, M.C.N., Brecht, J.K., Morais, A.M.M.B. & Sargent, S.A. (2005). Possible influences of water loss and polyphenol oxidase activity on anthocyanin content and discoloration in fresh ripe strawberry (cv. Oso Grande) during storage at 1°C. *Journal of Food Science*, 70(1), S90-95.
Fresh ripe strawberries were stored for 8 days at 1°C and 90-95% relative humidity. During storage the anthocyanin content of the strawberries was reduced by 43%, while the loss of total phenolics was found to be 44%.

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Olsson, M.E., Ekvall, J., Gustavsonn, K.E., Nilsson, J., Pillai, D. Sjöholm, Svensson, Åkesson, B. & Nyman, M.G.L. (2004). Antioxidants, low molecular weight carbohydrates and total antioxidant capacity in strawberries (Frangaria x ananassa): effects of cultivar, ripening and storage. *Journal of Agricultural and Food Chemistry*, 52(9), 2490-2498.

Ripe berries were stored at 4°C en relative humidity 85% up to 3 days. During the first day an increase of 15% was found for ascorbic acid. No statistically significant changes could be found during storage thereafter. Both water soluble and water insoluble total antioxidative capacity tended to decrease during the first two days of storage (-23% and -27% respectively in 1999; -15% and -66% respectively in 2000).

Pan, J., Vicente, A.R., Martinez, G.A., Chaves, A.R. & Civello, P.M. (2004). Combined use of UV-C irradiation and heat treatment to improve postharvest life of strawberry fruit. *Journal of the Science of Food and Agriculture*, 84(14), 1831-1838.

The effect of UV-C (4.1kJ/m) and heat treatment (45°C, 3h in air) either separately or combined on the quality of strawberries at the 75% or 50% surface red ripening stage were assessed. After treatment the trays were kept in darkness at 20°C.The heat-treated fruit had the lowest anthocyanin increase. UV-treated fruit showed a steady increase in anthocyanin concentration, but less than that observed in the control fruit. The combined treatment showed an intermediate pattern. The anthocyanin levels of UV-treated strawberries increased by 120% during 2 days of storage compared to the control at day 0, the heat treated strawberries by 60% and the combined treatment strawberries by 100%. The anthocyanin level of the control sample showed an increase of 180% over 2 days of storage. Total phenolic compounds remained approximately constant in control fruit for 2 days at 20°C. The UV-treated samples showed a decrease of 17.5% compared to the control and the heat treated samples of 32%. The combined treatment led to a decrease in total phenolic content of 11%.

Rababah, T.M., Ereifej, K.I. & Howard, L. (2005). Effect of ascorbic acid and dehydration on concentrations of total phenolics, antioxidant capacity, anthocyanins and color in fruits. *Journal of Agricultural and Food Chemistry*, 53(11), 4444-4447.

Strawberry, peach and apple were investigated. Drying increased the total phenolics of strawberries with 213% compared to fresh fruits. The anthocyanin content and antioxidant capacity increased with 285% and 275% respectively. For apples the drying process resulted in an increase of total phenolics, anthocynins and antioxidant capacity or 153%, 246% and 561% respectively. In peaches the total phenolics increased 282% by drying, the anthocyanins and antioxidant capacity increased 100% and 459% respectively.

Sahari, M.A., Boostani, F.M. & Hamidi, E.Z. (2004). Effect of low temperature on the ascorbic acid content and quality characteristics of frozen strawberry. *Food Chemistry*, 86(3), 357-363.

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Two different types of freezing methods (slow at -20°C and quick at -50 to 100°C) ,and three different temperatures (-12°C, -18°C, -24°C) were applied. The samples were stored for three months. The major losses of ascorbic acid occurred during the first 15 days of storage and the percentages were 64.5, 10.7 and 8.9 at -12, -18 and -24°C respectively. No statistically significant differences were observed between the different temperatures in ascorbic acid losses. The anthocyanin level decreased 40.2% for storage at -12°C during 3 months. At -18°C and -24°C there was a significant decrease in anthocyanin levels during the first 15 days of storage, resp. 34.3% and 17.6%. There was no effect of freezing method on ascorbic acid levels. Anthocyanin levels were influenced by freezing method. At all temperatures a higher anthocyanin level could be found for the slow-freezed samples. An increase of approximately 26%, 36% and 24% at resp. -12°C, -18°C and -24°C.

Sousa, M.B., Canet, W., Alvarez, M.D. & Tortosa, M.E. (2005). The effect of the pre-treatments and the long and short-term frozen storage on the quality of raspberry (cv. *Heritage*). *European Food Research and Technology*, 221(1-2), 132-144.
Results are presented of the effect of pre-treatments before freezing followed by long and short-term frozen storage (12 months at -18°C and 24 days suffering temperature fluctuations between -18°C and -12°C). Long term frozen storage at constant temperature caused a decrease of 21% in ascorbic acid content, while short term frozen storage at fluctuating temperatures led to a 25% decrease.

Strålsjö, L.M., Witthöft, C.M., Sjöholm, I.M. & Jägerstad, M.I. (2003). Folate content in strawberries (Fragaria x ananassa): effects of cultivar, ripeness, year of harvest, storage, and commercial processing. *Journal of Agricultural and Food Chemistry*, 51(1), 128-133.
Strawberries were stored unwrapped at room temperature (daylight) or 4°C (darkness) for between 0 and 9 days. Thereafter, strawberries were frozen at -20°C and kept at -20°C until analysis. The control samples were freshly frozen strawberries. Intact strawberries at 4°C showed a high stability of folate (99% retention). At 20°C the folate retention was lowered to 62%. Almost no losses of folate seemed to occur when strawberries were cooked to jam or stewed desserts from frozen berries. (retention 79-91%).

Suthanthangjai, W., Kajda, P. & Zabetakis, L. (2005). The effect of high hydrostatic pressure on the anthocyanins of raspberry (Rubus idaeus). *Food Chemistry*, 90(1-2), 193-197.
Samples were stored at 4°C, 20°C or 30°C for 9 days. Anthocyanin was measured on both treated and untreated samples. After 9 days at 4 °C the anthocyanins decreased by 19%, while at 20°C and 30°C this decrease was 40-73% and 77-81% respectively.

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Suutarinen, J., Honkapää, K., Heiniö, R.-L., Autio, K., Mustranta, A., Karppinen, S., Kiutamo, T., Liukkonen-Lilja, H. & Mokkila, M. (2002). Effects of calcium chloride-based prefreezing treatments on the quality factors of strawberry jams. *Journal of Food Science*, 67(2), 884-894.
Frozen storage of strawberries at -20°C for 2 months had no significant effect on the vitamin C content. After subsequent jam making only 13% of the vitamin C was retained, which decreased to 4% after 4 months of storage at 5°C.

Trierweiler, B., Krieg, M. & Tauscher, B. (2004). Antioxidative capacity of different apple cultivars after long-time storage. *Journal of Applied Botany and Food Quality*, 78(2), 117-119.

The effect of storage on the antioxidative capacity and vitamin C content of different apple cultivars was investigated. During 7 months of storage at 1°C, no significant effect on the antioxidative capacity was observed. With respect to the vitamin C content however, 4 out of 6 apple cultivars showed a 25-55% decrease, while no significant changes were found for the other 2 cultivars.

Vicente, A.R., Martinez, G.A., Civello, P.M. & Chaves, A.R. (2002). Quality of heat-treated strawberry fruit during refrigerated storage. *Postharvest Biology and Technology*, 25(1), 59-71.
Strawberries were heat treated in an air oven (45°C, 3h) and then stored at 0°C for 0,4 or 14 days. Afterward fruits were placed at 20°C and monitored after 24, 48 or 96h. When stored at 20°C, the control samples showed an increase in anthocyanins level of 250% after 96h. After 7 days at 0°C this increase was reduced to 160% after 96h and after 14 days at 0°C the increase was only 75% in 96h at 20°C.No significant difference in anthocyanins content was found immediately after heat treatment. When stored at 20°C, the heat-treated samples showed an increase in anthocyanins level of 80% in 96h. After 7 days at 0°C this increase was 140% and after 14 days at 0°C the increase was only 32% after 96h at 20°C.When fruits were held at 20°C, the heat treated fruits showed less anthocyanin accumulation than the controls. For the heat-treated samples this increase was 80% after 96h. After 7 days at 0°C, the amount of anthocyanins was lower in heat-treated fruits and the difference persisted after 96h of incubation at 20°C (control: 160% increase; heat-treated fruits: 140% increase).

Wicklund, T., Rosenfeld, H.J., Martinsen, B.K., Sundfor, M.W., Lea, P., Bruun, T., Blomhoff, R. & Haffner, K. (2005). Antioxidant capacity and colour of strawberry jam as influenced by cultivar and storage conditions. *Lebensmittel-Wissenschaft und-Technologie*, 38(4), 387-391.
Jam was prepared from frozen strawberries and kept at 4°C for one week. The jam was then stored at 4°C and 20°C , in darkness and under fluorescent light for 3 months. The anthocynanin content was highly influenced by the different storage conditions. The anthocyanin content at 20°C (+/- 10 mg/100g) was significantly lower compared to 4°C (+/- 30 mg/100g). Jam stored at 4°C had a higher

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content of anthocyanins and total oxidative capacity than samples stored at 20°C, while there was no significant difference between dark and light storage.

Yaman, O. & Bayoindirli, L. (2002). Effects of an edible coating and cold storage on shelf-life and quality of cherries. *Lebensmittel-Wissenschaft und-Technologie*, 35(2), 146-150.
Two groups of cherries were coated just after harvest with 10 and 20g/L Semperfresh. Half of the cherries of these groups were stored at room temperature (30+/-3°C) and at 40-50% relative humidity, the other half of the cherries were stored at 0°C and 95-98% relative humidity. The control group consisted of cherries with no Semperfresh coating. After 16 days at ambient temperature, the ascorbic acid content of the control group decreased by 61%, while after 30 days cold storage the ascorbic acid content decreased by 87%.Semperfresh fruit coating increased the shelf-life of the cherries by 21% at ambient temperature and by 26% at 0°C without perceptible losses in quality.

Zuo, L., Lee, E.J. & Lee, J.H. (2004). Effect of hot water treatment on quality of fresh-cut apple cubes. *Food Science and Biotechnology*, 13(6), 821-825.
Samples were immersed in 25°C water with temperature raised to 95°C at 10°C increments for 2 min and cooled down to storage temperature immediately after each heat treatment. Apple cubes were also treated with 1% ascorbic acid. Samples were placed in unsealed LDPE bags and stored at 4°C and 95% relative humidity for up to 6 days. As the temperature increased, amount of vitamin C retained in the sample decreased. Samples treated at 85 and 95°C retained only 64.0 and 57.4% vitamin C of the control, respectively.

8. ATTACHMENTS – TABLES FRUITS

8.1 Apple (*Malus pumila)*

8.2 Cherry (*Prunus avium*)

8.3 Peach (*Prunus persica*)

8.4 Raspberry (*Rubus idaeus*)

8.5 Strawberry (*Fragaria X ananassa*)

8.6 Other fruits

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OF PROCESSED FRUIT
& VEGETABLES

Addendum 2007
Tables vegetables

5.1 Broccoli (Brassica oleracea var. italica)

Nutrient	Fresh	Freezing/ Frozen storage	Cooking Reheating
Ascorbic acid (vitamin C)	- 6d, 5°C 15-25% retention (Kalt, 2005) - 20d, 1°C Decrease to half of initial level - 28d, 1°C, MAP No loss (Serrano et al., 2006) - 7d, 1°C, 95% RH + 3d, 15°C, 70-75%RH, MAP 2.4% + extra 11% loss (Vallejo et al., 2003a)		- microwave, 1 min, 30% of 700W 94,3% retention (adjusted for moisture loss) (Brewer & Begum, 2003) - microwave, 4 min, 100% of 700W 33,2% retention (adjusted for moisture loss) (Brewer & Begum, 2003) - high pressure boiling (3 min) 25% reduction - steaming (3.5 min) No reduction - microwaving (5 min) 46% reduction - boiling (5 min) 27% reduction (Vallejo et al., 2002) - processing (15 min) with and without pre-heating 100% and 0% left respectively (Yamaguchi et al., 2003) - boiling, 300s 68% loss - microwaving, 300s 68% loss - steaming, 10min: no significant effect (Gliszczyńska-świgło et al., 2006) - boiling, 5min: 23% loss (Gliszczyńska-świgło et al., 2006) - Frying (3min 30s in 125-140°C): loss (AA+DHAA) in peanut oil:41%, safflower oil: 40%, soybean oil: 48%, refined olive oil: 80%, extra virgin: no loss, sunflower oil: 8% (Moreno et al., 2007)
Beta-caroteen			- Boiling fresh broccoli, 25,5min, increase 440% (Bernhardt & Schlich, 2006) - Boiling frozen broccoli, 14 min, reduction 14% (Bernhardt & Schlich, 2006) - Stewing, fresh broccoli, 12 min, increase 360% (Bernhardt & Schlich, 2006) - Steaming fresh broccoli, 10 min, increase 320% (Bernhardt & Schlich, 2006) - Steaming frozen broccoli, 6 min, reduction 19% (Bernhardt & Schlich, 2006)

			- pressure steaming, fresh broccoli, 2min, increase 420% (Bernhardt & Schlich, 2006) - microwave frozen broccoli, 8 min, reduction 24% (Bernhardt & Schlich, 2006) - steaming, 10min: 1,9 fold increase (Gliszczyńska-świgło et al., 2006) - boiling, 5min: 2,3 fold increase (Gliszczyńska-świgło et al., 2006)
Alfa-tocoferol (vitamin E)			- Boiling fresh broccoli, 25,5min, increase 381% (Bernhardt & Schlich, 2006) - Boiling frozen broccoli, 14 min, reduction 5% (Bernhardt & Schlich, 2006) - Stewing, fresh broccoli, 12 min, increase 403% (Bernhardt & Schlich, 2006) - Steaming fresh broccoli, 10 min, increase 394% (Bernhardt & Schlich, 2006) - Steaming frozen broccoli, 6 min, increase 13% (Bernhardt & Schlich, 2006) - pressure steaming, fresh broccoli, 2min, increase 431% (Bernhardt & Schlich, 2006) - microwave frozen broccoli, 8 min, increase 8 % (Bernhardt & Schlich, 2006) - steaming, 10min: 1, 2 and 1,4 fold increase (α- and γ- tocoferol) (Gliszczyńska-świgło et al., 2006) - boiling, 5min: 1,7 fold increase (Gliszczyńska-świgło et al., 2006)
Carotenoids	- 6d, 5°C 50% retention (Kalt, 2005)		- boiling, 300s 22% loss - microwaving, 300s 21% loss (Zhang & Hamauzu, 2004) - steaming, 10min: 4,1 fold increase of lutein (Gliszczyńska-świgło et al., 2006) - boiling, 5min: 6 fold increase of lutein (Gliszczyńska-świgło et al., 2006) - conventional boil, 7min: 77,6%, 88;4% and no detection of β-carotene, lutein/zeaxanthin and α-carotene respectively (Nunn et al., 2006) - induction boil, 7min: 90.3%, 96.6% and no detection of β-carotene, lutein/zeaxanthin and α-carotene respectively (Nunn et al., 2006) - microwave steam, 6min: 62.2%, 85.5% and no detection of β-carotene, lutein/zeaxanthin and α-carotene respectively (Nunn et al., 2006)
Folic acid			- Boiling, 100°C, 10 min

			44% retention (McKillop et al., 2002) - Steaming 15 min 100% retention (McKillop et al., 2002) - blanching (5s): no losses - blanched (5s), cooled (20°C,1h), reheated (100°C, 5 min): 13% losses - blanched (5s), sous vide processed (90°C, 7min): 16.5% losses - steamed (100°C, 5min): 36.5% losses - steamed (100°C, 5min,), held warm (60°C, 2h): 27% losses - steamed (100°C, 5min), held warm '60°C, 2h), cooled (4°C, 24h), reheated '100°C, 5min): 23.5% losses - steamed,
Glucosinolate	- 7d, 1°C, 95% RH + 3d, 15°C, 70-75%RH, MAP 71% + extra 9% loss (Vallejo et al., 2003a)		- Boiling 61% retention (McNaughton & Marks, 2003) - Boiling frozen broccoli 41% retention (McNaughton & Marks, 2003)
Glucosinolate	- 7d, 1°C, 95% RH + 3d, 15°C, 70-75%RH, MAP 71% + extra 9% loss(Vallejo et al., 2003a) - storage 7 days (12-22°C): no significant loss (Song & Thornalley, 2007) - Storage 7 days (4-8°C): 27% total loss glucosinolates (Song & Thornalley, 2007) - shredding (6h, 25°C): 47% total loss (Song & Thornalley, 2007)	- frozen storage (-85°C, 2 months) without prior blanching: 33% total loss glucosinolates (Song & Thornalley, 2007)	- high pressure boiling (3 min) 52% reduction - steaming (3.5 min) 7% increase - microwaving (5 min) 74% reduction - boiling (5 min) 74% reduction (Vallejo et al., 2002) - steaming, 10min: 1,2 fold increase (Gliszczyńska-świgło et al., 2006) - boiling, 5min: 40% loss (Gliszczyńska-świgło et al., 2006) - cooking 30min, boiling water: 77% total losses (Song & Thornalley, 2007) - steaming 650W, 20min: no significant losses (Song & Thornalley, 2007) - microwave, 900W, 180s, 10% water: no significant losses (Song & Thornalley, 2007) - stir frying (5min in 15% sunflower cooking oil, 110-120°C): no significant losses (Song & Thornalley, 2007) - Frying (3min 30s in 125-140°C): loss refined olive oil: 49%, sunflower oil: 37%; in peanut , safflower , soybean and , extra virgin olive oil: no significant loss

			(Moreno et al., 2007)
Glucoraphanin	- 7d, 20°C, packed 56% loss - 3d, 20°C 55% loss - 7d, 4°C, packed or non packed No loss - 7d, 4°C, air or controlled atmosphere, packed No loss - 10d, 4°C or 20°C, MAP No loss (Rangkadilok et al., 2002) - 2, 7, 28 days at 1°C or 4°C followed by 3 days simulated marketing at 8, 15 or 20°C; no significant difference and loss for all treatments (Winkler et al., 2007).		
Phenolic compounds	- 6d, 20°C, dark doubled (Costa et al., 2006) - 28d, 1°C 40% loss - 28d, 1°C, MAP No loss (Serrano et al., 2006) - 10d, 5°C 25-30% increase - 3d, 20°C 50-70% increase (Starzynska et al., 2003)	- washing, blanching, freezing 41,6% retention (Ninfali & Bacchiocca, 2003)	- Boiling, steaming, micro-waving 94% retention, 18 % increase and 25% increase resp. (Turkmen et al., 2005) - high pressure boiling (3 min) 44% reduction - steaming (3.5 min) 3% reduction - microwaving (5 min) 80% reduction - boiling (5 min) 54% reduction (Vallejo et al., 2003b) - processing (15 min) with and without pre-heating No loss in both cases (Yamaguchi et al., 2003)
Phenolic compounds			- boiling, 300s 72% loss - microwaving, 300s 72% loss (Zhang & Hamauzu, 2004) - steaming, 10min: 1,6 fold increase (Gliszczyńska-świgło et al., 2006) - boiling, 5min: 13% loss (Gliszczyńska-świgło et al., 2006) - Frying (3min 30s in 125-140°C): no significant loss of caffeoyl quinic acid in peanut, safflower , soybean, refined olive, extra virgin olive and sunflower oil (Moreno et al., 2007). - Frying (3min 30s in 125-140°C): loss of sinapic acid

			derivatives in peanut oil:no loss, safflower oil: 44%, soybean oil: <40%, refined olive oil: 70%, extra virgin: <69%, sunflower oil: 55% (Moreno et al., 2007)
Total antioxidant power	- 4d, 20°C, dark 70% decrement (Costa et al., 2005) -6d, 20°C, dark 65% remaining (Costa et al., 2006) - 28d, 1°C 30% loss - 28d, 1°C, MAP 14-28% loss (Serrano et al., 2006)		- precooking, 50°C / 40 min, cooking 8 min, precooking + cooking No difference with fresh, reduction from 90% to 79%, reduction from 90% to 82.5% (ferrous ion chelating activity) Reduction from 71% to 31%, reduction from 71% to 50%, reduction from 71% to 50% (DPPH radical scavenging activity) (Lin & Change, 2005) - boiling, 300s 35% retention - microwaving, 300s 35% retention (Zhang & Hamauzu, 2004)
Antiradical activity	- 3d, 20°C Doubled - 3d, 5°C No change (Starzynska et al., 2003)		- processing (15 min) with and without pre-heating no and 6% left respectively (Yamaguchi et al., 2003)
Total flavonoids	- 4d, 20°C, dark doubled (Costa et al., 2006) - 7d, 5°C 10-20% increase - 3d, 20°C 25-40% increase (Starzynska et al., 2003) -7d, 1°C, 95% RH + 3d, 15°C, 70-75%RH, MAP 61% + no extra loss (Vallejo et al., 2003a) - 2, 7, 28 days at 1°C or 4°C followed by 3 days simulated marketing at 8, 15 or 20°C; no significant loss of quercetin and kaempferol for all treatments (Winkler et al., 2007).		- high pressure boiling (3 min) 53% reduction - steaming (3.5 min) 11% reduction - microwaving (5 min) 97% reduction - boiling (5 min) 81% reduction (Vallejo et al., 2003b) - Frying (3min 30s in 125-140°C): loss of flavonoids in peanut oil:21%, safflower oil: 35%, soybean oil: 31%, refined olive oil: 50%, extra virgin: 52%, sunflower oil: 38% (Moreno et al., 2007)
Minerals			Frying (3min 30s in 125-140°C): no significant loss of Iron, Manganese, Zinc, Copper, Potassium, Sodium, Calcium, Magnesium in peanut, safflower , soybean, refined olive, extra virgin olive and sunflower oil (Moreno et al., 2007).

5.2 Cabbage (Brassica oleracea var. capitata)

Nutrient	Fresh	Blanching	Canning Jarring	Cooking Reheating
Glucosinolate		- 95°C, 3 min 100% retention in red cabbage (Oerlemans et al., 2006)	- 120°C, 40 min 27% retention in red cabbage (Oerlemans et al., 2006)	- Boiling 72% retention (McNaughton & Marks, 2003) - Boiling red cabbage 82% retention (McNaughton & Marks, 2003) - 100°C, 40min 89% retention in red cabbage (Oerlemans et al., 2006)
Dietary fibre Neutral detergent fibre NDF				- Cooking, 10 min on hot plate 80,4% retention (Rehman et al., 2003) - Pressure cooking, 10 min 73,0% retention (Rehman et al., 2003) - Microwave cooking, 10 min 85,1% retention (Rehman et al., 2003)
Dietary fibre Acid detergent fibre ADF				- Cooking, 10 min on hot plate 62,2% retention (Rehman et al., 2003) - Pressure cooking, 10 min 58,1% retention (Rehman et al., 2003) - Microwave cooking, 10 min 66,2% retention (Rehman et al., 2003)
Insoluble dietary fibre IDF	- >6 weeks increase (Wennberg et al., 2002)			
Soluble dietary fibre SDF	- >6 weeks decrease (Wennberg et al., 2002)			
Phenolic compound		- water blanching 100°C, 1 minute 80 % retention(Amin et al., 2004)		

5.3 Carrot (Daucus carota)

Nutrient	Blanching	Freezing/ Frozen storage	Cooking Reheating
Phenolic compound: chlorogenic acid			- Cooking in low volume water: 74,6% retention (Andlauer et al., 2003) - Cooking in large amount of water: 37,2% retention (Andlauer et al., 2003)
Phenolic compounds		- washing, blanching, freezing 59,6% retention (Ninfali & Bacchiocca, 2003)	
β-carotene (provitamin A)	- 100°C, 3 min 17,6% increase (Dutta et al., 2004) - 100°C, 5 min 1,1% increase (Dutta et al., 2004)	- 80d, 0°C, blanched, 3 min, 100°C 59,8% retention (Dutta et al., 2004) - 80d, 0°C, blanched, 5 min, 100°C 68,5% retention (Dutta et al., 2004) - 80d, -18°C, blanched, 3 min, 100°C 98,8% retention (Dutta et al., 2004) - 80d, -18°C, blanched, 5 min, 100°C 93,5% retention (Dutta et al., 2004)	- Boiling, 10 min 84% retention (Gayathri et al., 2004) - Pressure cooking, 10 min 73% retention (Gayathri et al., 2004) - Boiling, 10 min in presence of various spices/acidulants 73-96% retention (Gayathri et al., 2004) - Pressure cooking, 10 min in presence of various spices/acidulants 80-97% retention (Gayathri et al., 2004)
Lycopene			- 2h, 100 and 140°C 75 and 25% retention resp. (Mayer-Miebach et al., 2005)
Ascorbic acid (vitamin C)	- Microwave blanching 2,0 min, pulsed method 82,6% retention (Ramesh et al., 2002) - Water blanching 98°C, 2,0 min 41,9% retention (Ramesh et al., 2002)		

5.3 Carrot (Daucus carota) Continued

Nutrient	Blanching	Freezing/ Frozen storage	Cooking Reheating
Dietary fibre Neutral detergent fibre NDF			- Cooking, 10 min on hot plate 84,4% retention (Rehman et al., 2003) - Pressure cooking, 10 min 74,1% retention (Rehman et al., 2003) - Microwave cooking, 10 min 78,5% retention (Rehman et al., 2003)
Dietary fibre Acid detergent fibre ADF			- Cooking, 10 min on hot plate 74,1% retention (Rehman et al., 2003) - Pressure cooking, 10 min 65,2% retention (Rehman et al., 2003) - Microwave cooking, 10 min 67,4% retention (Rehman et al., 2003)

5.4 Cauliflower (Brassica oleracea var. botrytis)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Cooking Reheating
Glucosinolate	- 0°C, dark, air Increase on day 28, constant thereafter - 0°C, dark, controlled atmosphere No change between 14d and 56 d (Hodges et al., 2006)			- Boiling 68% retention (McNaughton & Marks, 2003) - Boiling frozen cauliflower 69% retention (McNaughton & Marks, 2003)
Dietary fibre Neutral detergent fibre NDF				- Cooking, 10 min on hot plate 80,3% retention (Rehman et al., 2003) - Pressure cooking, 10 min 75,6% retention (Rehman et al., 2003) - Microwave cooking, 10 min 86,6% retention (Rehman et al., 2003)
Dietary fibre Acid detergent fibre ADF				- Cooking, 10 min on hot plate 66,9% retention (Rehman et al., 2003) - Pressure cooking, 10 min 64,6% retention (Rehman et al., 2003) - Microwave cooking, 10 min 73,2% retention (Rehman et al., 2003)
Folate	- 4°C, 24h 15% loss (Melse-Boonstra et al., 2002)	- 8 min 10% loss (Melse-Boonstra et al., 2002)	- freezing (-18°C, 16h), thawing (4°C, 24h) and blanching (8 min) 65% loss - blanching (8 min), freezing (-18°C, 16h) and thawing (4°C, 24h) 16% loss (Melse-Boonstra et al., 2002)	- steaming (7 min) 8% loss (Melse-Boonstra et al, 2002)

5.4 Cauliflower (Brassica oleracea var. botrytis) Continued

Nutrient	Fresh	Blanching	Cooking Reheating
Vitamin C (white cauliflower variety)		- 95-98°C, 3 min, reduction 21,2%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 34,6% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 35,3% (Gebzynski & Kmiecik, 2007 - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 50,9% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 60,8% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 70,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 39,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 50,8% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 42,8% (Gebzynski & Kmiecik, 2007)
Vitamin C (green cauliflower variety)		- 95-98°C, 3,5 min, reduction 25,9%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 32,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 33,7% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 46,7% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 58,3% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 63,3% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 41,6% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 51,0% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 57,5% (Gebzynski & Kmiecik, 2007)
carotenoids (white cauliflower variety)		- 95-98°C, 3 min, no change	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 7,7% (Gebzynski & Kmiecik, 2007)

			- freezing to -30°C and boiling, 5 min, reduction 7,7% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 7,7% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 15,4% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 15,4% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 7,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 7,7 (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 7,7% (Gebzynski & Kmiecik, 2007)
carotenoids (green cauliflower variety)		- 95-98°C, 3,5 min, reduction 14,1%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 12,9% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 14,1% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 16,0% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 19,1% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 12,5% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 14,1% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 13,7 (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 2,7% (Gebzynski & Kmiecik, 2007)
Beta-carotene (white cauliflower variety)		- 95-98°C, 3 min, reduction 25,0%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, no change (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, no change (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, no change (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 25,0% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 25,0% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, no change (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, no change (Gebzynski & Kmiecik, 2007)

			- freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, no change (Gebzynski & Kmiecik, 2007)
Beta-carotene (green cauliflower variety)		- 95-98°C, 3,5 min, reduction 6,7%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 13,3% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 13,3% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 33,3% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 40,0% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 46,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 20,0% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 20,0 (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 26,7% (Gebzynski & Kmiecik, 2007)
polyphenols (white cauliflower variety)		- 95-98°C, 3 min, reduction 6,1%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 9,5% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 9,9% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 11,6% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 14,5% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 17,5% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 10,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 12,2% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 14,6% (Gebzynski & Kmiecik, 2007)
polyphenols (green cauliflower variety)		- 95-98°C, 3,5 min, reduction 9,3%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 16,4% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 15,8% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 20,4% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 23,3% (Gebzynski & Kmiecik, 2007)

			- freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 30,8% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 19,5% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 21,9 (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 27,9% (Gebzynski & Kmiecik, 2007)
Antioxidant activity (%RSA) (white cauliflower variety)		- 95-98°C, 3 min, reduction 13,2%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 48,6% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 48,6% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 55,4% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 63,6% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 75,9% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 54,0% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 61,1% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 73,0% (Gebzynski & Kmiecik, 2007)
Antioxidant activity (%RSA) (green cauliflower variety)		- 95-98°C, 3,5 min, reduction 13,2%	After blanching and compared to raw product: - freezing to -20°C and boiling, 5 min, reduction 38,2% (Gebzynski & Kmiecik, 2007) - freezing to -30°C and boiling, 5 min, reduction 38,2% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 4 months at -20°C and boiling, 5 min, reduction 45,5% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 8 months at -20°C and boiling, 5 min, reduction 51,8% (Gebzynski & Kmiecik, 2007) - freezing to -20°C, storage for 12 months at -20°C and boiling, 5 min, reduction 62,9% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 4 months at -30°C and boiling, 5 min, reduction 42,9% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 8 months at -30°C and boiling, 5 min, reduction 49,7% (Gebzynski & Kmiecik, 2007) - freezing to -30°C, storage for 12 months at -30°C and boiling, 5 min, reduction 60,3% (Gebzynski & Kmiecik, 2007)

5.5 Green bean (Phaseolus vulgaris)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Cooking Reheating
Phenolic compound: rutin				- Cooking in low volume water: 98,2% retention (Andlauer et al., 2003) - Cooking in large amount of water: 70,3% retention (Andlauer et al., 2003)
Phenolic compound: quercitin				- Cooking in low volume water: 99,1% retention (Andlauer et al., 2003) - Cooking in large amount of water: 73,3% retention (Andlauer et al., 2003)
Free total phenolic compounds				- 115°C, 10 min 60% retention (Jiratanan & Liu, 2004)
Free flavonoids				- 115°C, 10 min 40% retention (Jiratanan & Liu, 2004)
Ascorbic acid (vitamin C)	- 16d, 5°C 8 % retention (Kalt, 2005)	- 70°C, 2 min 69,1% retention (Bahçeci et al., 2005) - 90°C, 3 min 59,9% retention (Bahçeci et al., 2005)	- 6 months, -18°C, unblanched 6,3% retention (Bahçeci et al., 2005) - 6 months, -18°C blanched, 70°C, 2 min 13, 8% retention (Bahçeci et al., 2005) - 6 months, -18°C blanched, 90°C, 3 min 31,6% retention (Bahçeci et al., 2005)	- Microwave, 3 min, 100% of 700W < 50% retention (adjusted for moisture loss) (Brewer & Begum, 2003) - Microwave, 4 min, 70% of 700W < 50% retention (adjusted for moisture loss) (Brewer & Begum, 2003) - 115°C, 10, 20 and 40 min 87,8, 93,8 and 95,9% retention resp. (Jiratanan & Liu, 2004) - 20 min, 100, 115 and 121°C 99,8, 93,8 and 96,6% retention resp. (Jiratanan & Liu, 2004) - Boiling, 30 min 22,4% retention (Kala & Prakash, 2006) - Pressure cooking, 25 min 9,9% retention (Kala & Prakash, 2006) - Micro-waving, 30 min 12,6% retention (Kala & Prakash, 2006)

5.5 Green bean (Phaseolus vulgaris) Continued

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Cooking Reheating
Ascorbic acid (vitamin C)				- No thawing, in stainless steel pan 81,8% retention (Nursal & Yucecan, 2000) - No thawing, in pyrex pan 57,9% retention (Nursal & Yucecan, 2000) - Thawing, in pyrex pan 51,6% retention (Nursal & Yucecan, 2000)
Dietary fibre				- Boiling, 30 min 81,0% retention (Kala & Prakash, 2006) - Pressure cooking, 25 min 91,6% retention (Kala & Prakash, 2006) - Micro-waving, 30 min 81,0% retention (Kala & Prakash, 2006)
Calcium				- Boiling, 30 min 98,7% retention (Kala & Prakash, 2006) - Pressure cooking, 25 min 94,9% retention (Kala & Prakash, 2006) - Micro-waving, 30 min 100% retention (Kala & Prakash, 2006)
Phosphorus				- Boiling, 30 min 89,5% retention (Kala & Prakash, 2006) - Pressure cooking, 25 min 100% retention (Kala & Prakash, 2006) - Micro-waving, 30 min 100% retention (Kala & Prakash, 2006)

5.5 Green bean (Phaseolus vulgaris) Continued

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Cooking Reheating
Phenolic compounds				- Boiling, steaming, micro-waving 14, 30 and 29% increase resp. (Turkmen et al., 2005)
Iron				- Boiling, 30 min 93,5% retention (Kala & Prakash, 2006) - Pressure cooking, 25 min 100% retention (Kala & Prakash, 2006) - Micro-waving, 30 min 99,6% retention (Kala & Prakash, 2006)
Folate	- 4°C, 24h 7% increase (Melse-Boonstra et al., 2002)	- 6 min 21% loss (Melse-Boonstra et al., 2002)	- freezing (-18°C, 16h), thawing (4°C, 24h) and blanching (6 min) 79% loss - blanching (6 min), freezing (-8°C, 16h) and thawing (4°C, 24h) 35% loss (Melse-Boonstra et al., 2002)	- steaming (6 min) 10% loss (Melse-Boonstra et al, 2002)

5.6 Green pea (Pisum sativum)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Canning Jarring	Cooking Reheating
Ascorbic acid (vitamin C)		- 70°C, 4 min 99,0% retention (Gökmen et al., 2004) - 80°C, 2 min 98,4% retention (Gökmen et al., 2004)	- 12 months, -18°C unblanched 9,4% retention (Gökmen et al., 2004) - 12 months, -18°C blanched, 70°C, 4 min 55,1% retention (Gökmen et al., 2004) - 12 months, -18°C blanched, 80°C, 2 min 64,7% retention (Gökmen et al., 2004) - 6 weeks, -18°C steam-blanched 58,6% retention (Lin & Brewer, 2005) - 12 weeks, -18°C steam-blanched 65,5% retention (Lin & Brewer, 2005) - 6 weeks, -18°C water-blanched 37,9% retention (Lin & Brewer, 2005) - 12 weeks, -18°C water-blanched 41,4% retention (Lin & Brewer, 2005)	- 130°C, agitation = 5 rpm, headspace = 12 mm 80,3% retention (Garotte et al., 2006)	- No thawing, in stainless steel pan 74,8% retention (Nursal & Yucecan, 2000) - No thawing, in pyrex pan 64,0% retention (Nursal & Yucecan, 2000) - Thawing, in pyrex pan 59,2% retention (Nursal & Yucecan, 2000)
Dehydroascorbic Acid (vitamin C)		- 70°C, 4 min 92,1% retention (Gökmen et al., 2004) - 80°C, 2 min 77,7% retention (Gökmen et al., 2004)			

5.6 Green pea (Pisum sativum) Continued

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Canning Jarring	Cooking Reheating
Dietary fibre Neutral detergent fibre NDF					- Cooking, 10 min on hot plate 86,2% retention (Rehman et al., 2003) - Pressure cooking, 10 min 77,4% retention (Rehman et al., 2003) - Microwave cooking, 10 min 83,0% retention (Rehman et al., 2003)
Dietary fibre Acid detergent fibre ADF					- Cooking, 10 min on hot plate 73,3% retention (Rehman et al., 2003) - Pressure cooking, 10 min 67,6% retention (Rehman et al., 2003) - Microwave cooking, 10 min 69,8% retention (Rehman et al., 2003)
Phenolic compounds					- Boiling, steaming, micro-waving 84, 95 and 90% retention resp. (Turkmen et al., 2005)
Antioxidant activity	- at 4 °C and 20 °C no effect on lipid-soluble activity (Hunter and Fletcher, 2002)	- water blanching 97 °C, 85s 30 % retention of water-soluble activities (Hunter and Fletcher, 2002)	- Freezing 76 % retention (Hunter and Fletcher, 2002)	- Jarring 42 % retention (Hunter and Fletcher, 2002) - Canning 41 % retention (Hunter and Fletcher, 2002)	

5.7 Onion (Allium cepa)

Nutrient	Fresh	Washing Peeling Trimming	Freezing/ Frozen storage	Cooking Reheating
Flavonoids - Antioxidant capacity				- Boiling 6-23 min: 65,6% retention (Agostini et al., 2004) - Steam cooking 3-22 min: 67,7% retention (Agostini et al., 2004) - Micro-waving 1,3-2,5 min: 70,9% (Agostini et al., 2004) - Dry heat: 9-31 min: 88,8% retention (Agostini et al., 2004)
Phenolic compound: anthocyanins		- Bulb peeling 27% retention (Gennaro et al., 2002)		
Phenolic compound: quercitin		- Bulb peeling 79% retention (Gennaro et al., 2002)		- Sautéing, 1 min, 93°C 25% increase (Lombard et al., 2005) - Baking, 15 min, 176°C 7% increase (Lombard et al., 2005) - Boiling, 5 min, 100°C 82% retention (Lombard et al., 2005)
Phenolic compounds			- washing, blanching, freezing 114% increase (Ninfali & Bacchiocca, 2003)	
Total Phenolics		Increase 15% in first 2 weeks Decrease of 45% after next 8 weeks (Benkeblia & Shiomi, 2004)		

5.7 Onion (Allium cepa) Continued

Nutrient	Fresh	Washing Peeling Trimming	Freezing/ Frozen storage	Cooking Reheating
Anitoxidant activity				- Boiling, 10,30 or 60 min, 20-4O% reduction of TEAC and FRAP values in yellow and red onion and in white Welsh onion (Aoyama & Yamamoto, 2007) - Boiling, 10, 30 min, unspecified increase in TEAC and FRAP values in green Welsh onion (Aoyama & Yamamoto, 2007)
Dietary fibre Neutral detergent fibre NDF				- Cooking, 10 min on hot plate 82,3% retention (Rehman et al., 2003) - Pressure cooking, 10 min 67,3% retention (Rehman et al., 2003) - Microwave cooking, 10 min 77,0% retention (Rehman et al., 2003)
Dietary fibre Acid detergent fibre ADF				- Cooking, 10 min on hot plate 72,6% retention (Rehman et al., 2003) - Pressure cooking, 10 min 58,4% retention (Rehman et al., 2003) - Microwave cooking, 10 min 67,3% retention (Rehman et al., 2003)
Dietary fibre Total fructooligiosaccharides	Storage at 15°C Total FOS: steady state 1st 6 weeks, decrease of 74% in the 18th week (Benkeblia et al. 2005)			

5.8 Spinach (Spinacia oleracea)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Canning Jarring	Cooking Reheating
Folic acid	- At 4°C/8d or 10°C/6d or 20 °C/4d 53 % retention (Pandrangi & Laborde, 2004)				- Boiling, 100°C, 3,5 min 49% retention (McKillop et al., 2002) - Steaming 4,5 min 100% retention (McKillop et al., 2002)
Phenolic compounds		- water blanching 100°C, 1 min 86 % retention (Amin et al., 2004)	- washing, blanching, freezing 32,9% retention (Ninfali & Bacchiocca, 2003)		- Boiling, steaming, micro-waving 1, 3 and 9% increase resp. (Turkmen et al., 2005)
Ascorbic acid (vitamin C)	- at 2 °C 25 % retention after 9 days storage in polypropylene bags (Bergquist et al., 2006) - at 10 °C 0 % retention after 9 days storage in polypropylene bags (Bergquist et al., 2006)	- Microwave blanching 3,2 min, pulsed method 68,9% retention (Ramesh et al., 2002) - Water blanching 98°C, 1,5 min 51,0% retention (Ramesh et al., 2002)			- Boiling, 100 °C, 4,5 min 75 % retention - Overcooking, 100 °C, 8 min 26 % retention - No thawing, in stainless steel pan 53,5% retention (Nursal & Yucecan, 2000) - No thawing, in pyrex pan 41,5% retention (Nursal & Yucecan, 2000) - Thawing, in pyrex pan 39,7% retention (Nursal & Yucecan, 2000)
Antioxidant activity	- at 4 and 20 °C no effect on lipid-soluble activity (Hunter and Fletcher, 2002)	- Water blanching 97°C, 90 s 50 % retention of water-soluble activity (Hunter and Fletcher, 2002)	-Frozen leaf 76 % retention (Hunter and Fletcher, 2002) - Frozen chopped 52 % retention (Hunter and Fletcher, 2002)	- Canning 26 % retention (Hunter and Fletcher, 2002)	- Overcooking, 100 °C, 8 min 60 % retention (Hunter and Fletcher, 2002)
Carotenoïds	- at 2 °C 13 % rised after 9 days of storage (Bergquist et al., 2006) - at 10 °C 14 % rised after 9 days of storage (Bergquist et al., 2006)				

5.8 Spinach (Spinacia oleracea) Continued

Carotenoids continued	- at 7-9°C 58 % retention of β-carotene 68 % retention of lutein 20 % retention of violaxanthin 20 % retention of neoxanthin (Azevedo-Meleiro and Rodriguez-Amaya, D.B., 2005) - at 4°C during 8 d 54 % retention (Pandrangi et al., 2004) - at 10°C during 6 d 61 % retention (Pandrangi et al., 2004) - at 20°C during 4 d 44 % retention (Pandrangi et al., 2004)				
Dietary fibre Neutral detergent fibre NDF					- Cooking, 10 min on hot plate 80,5% retention (Rehman et al., 2003) - Pressure cooking, 10 min 70,8% retention (Rehman et al., 2003) - Microwave cooking, 10 min 82,2% retention (Rehman et al., 2003)
Dietary fibre Acid detergent fibre ADF					- Cooking, 10 min on hot plate 58,6% retention (Rehman et al., 2003) - Pressure cooking, 10 min 58,4% retention (Rehman et al., 2003) - Microwave cooking, 10 min 59,5% retention (Rehman et al., 2003)
Vitamin B 2 (riboflavin)					- Heating, 50°C during 10 minutes 99 % retention (Nisha et al., 2005) - Heating, 120°C during 60 minutes 77 % retention (Nisha et al., 2005)

5.8 Spinach (Spinacia oleracea) Continued

Vitamin B 2 (riboflavin) continued					- Open pan cooking 96 % retention (Nisha et al., 2005) - Pressure cooking 95 % retention (Nisha et al., 2005) - Ecocooking 88 % retention (Nisha et al., 2005)
Flavonoids	- normal retail storage conditions no considerable variation (Bergquist et al., 2005)				

5.9 Bell pepper (Capsicum annuum)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Cooking Reheating
Vitamin C		- Microwave blanching 4,8 min, pulsed method 84,7% retention (Ramesh et al., 2002) - Water blanching 98°C, 4,5 min 76,2% retention (Ramesh et al., 2002) - 12 days, 25°C, reduction 72% (Ayranci et al., 2004		
Beta-caroteen				- Boiling fresh pepper, 25,5min, reduction 35% (Bernhardt & Schlich, 2006) - Boiling frozen pepper, 14 min, reduction 24,5% (Bernhardt & Schlich, 2006) - Stewing, fresh pepper, 12 min, reduction 40% (Bernhardt & Schlich, 2006) - Steaming fresh pepper, 10 min, reduction 37% (Bernhardt & Schlich, 2006) - Steaming frozen pepper, 6 min, reduction 14% (Bernhardt & Schlich, 2006) - pressure steaming, fresh pepper, 2min, increase 28% (Bernhardt & Schlich, 2006) - microwave frozen pepper 8 min, reduction 20% (Bernhardt & Schlich, 2006)
Vitamin E				- Boiling fresh pepper, 25,5min, reduction 8,7% (Bernhardt & Schlich, 2006) - Boiling frozen pepper, 14 min, increase 3,1% (Bernhardt & Schlich, 2006) - Stewing, fresh pepper, 12 min, reduction 12,3% (Bernhardt & Schlich, 2006) - Steaming fresh pepper, 10 min, reduction 13,8% (Bernhardt & Schlich, 2006) - Steaming frozen pepper, 6 min, reduciton 4,3% (Bernhardt & Schlich, 2006) - pressure steaming, fresh pepper, 2min, decrease 5,9% (Bernhardt & Schlich, 2006) - microwave frozen pepper, 8 min, increase 3,8 % (Bernhardt & Schlich, 2006)

Phenolic compounds				- Boiling, steaming, micro-waving 14, 2 and 26% increase resp. (Turkmen et al., 2005)

5.10 Brussels sprouts (Brassica oleracea var. gemmifera)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Canning Jarring	Cooking Reheating
Ascorbic acid (vitamin C)	- storage 42days, 0°C, 84.8%RH in PVC: no significant change (Viña et al.,2007a). - storage 42 days, 0°C, 84.8% RH in glycerol/starch-based coating and PVC: no significant change(Viña et al.,2007a).	- blanching 1, 3 and 5 minutes in boiling water: no significant change for 1 and 3min; reduction 24% for 5min (Viña et al., 2007b) - preblanching 5min, 50°C followed by blanching 3 min, boiling water: 19% decrease (Viña et al., 2007b). - preblanching by microwave heating 5min, 700 W followed by blanching 2 min, boiling water: +/-18% increase (Viña et al., 2007b).	- after blanching (4.5 min at 93–95 1C) and freezing, loss of vitamin C was 34% (Czarniecka-Skubina; 2002).	- after blanching and canning, loss of vitamin C was 66% (Czarniecka-Skubina; 2002).	- for cooking in a microwave oven, pressure cooker in steam and acuthermal pot, losses of vitamin C were from 3.7% to10.6%.Traditional cooking in a pot starting with cold water in pressure cooker starting with boiling water, and in a pot starting with boiling water (27.6%) showed losses of 38.6%, 31.3% en 27.6% respectively (Czarniecka-Skubina; 2002).
Antioxidant activity	- storage 42days, 0°C, 84.8%RH in PVC: 56% increase (Viña et al.,2007a). - storage 42 days, 0°C, 84.8% RH in glycerol/starch-based coating and PVC: 31% increase (Viña et al.,2007a).	- blanching 1, 3 and 5 min in boiling water: increase of +/- 10, 50, 60% (Viña et al., 2007b). - preblanching 5min, 50°C followed by blanching 3 min, boiling water: +/- 70% increase (Viña et al., 2007b). - preblanching by microwave heating 5min, 700 W followed by blanching 2 min, boiling water: 100% increase (Viña et al., 2007b).			
Carotenoïds					- cooking (15min) of frozen sprouts: increase of lutein (1,8%) and decrease of β-carotene (6%) Hart & Scott (1995).

	Fresh	Washing, peeling, trimming	Blanching	Freezing/ Frozen storage	Cooking Reheating
Glucosinolate	- storage 7 days (12-22°C): no significant loss (Song & Thornalley, 2007) - Storage 7 days (4-8°C): 20% total loss glucosinolates (Song & Thornalley, 2007)	- shredding (5*5*5 mm cubs, 6h, 25°C): 75% total loss (Song & Thornalley, 2007) - shredding (quartering, 6h, 25°C): loss <10% (Song & Thornalley, 2007)		- frozen storage (-85°C, 2 months) without prior blanching: 33% total loss glucosinolates (Song & Thornalley, 2007)	- cooking 30min, boiling water: 58% total losses (Song & Thornalley, 2007) - steaming 650W, 20min: no significant losses (Song & Thornalley, 2007) - microwave, 900W, 180s, 10% water: no significant losses (Song & Thornalley, 2007) - stir frying (1cm strips, 5min in 15% sunflower cooking oil, 110-120°C): no significant losses (Song & Thornalley, 2007)
Minerals			- blanching (T95-98°C, 5min) (Kmiecik et al., 2007): Ash : 16% reduction P :no reduction K: 14% reduction Ca: no reduction Mg: 12% reduction Na: no reduction Fe: 13% reduction Zn: 19% reduction Mn: 19% reduction Cu: 13% reduction Cr: 50% reduction Ni: no reduction		- Boiling of fresh and frozen Brussels sprouts led to an glucosinalate retention of 55-60% and 68% respectively (McNaughton & Marks, 2003). - cooking in a microwave oven, pressure cooker in steam and acuthermal pot, losses of vitamin C were from 3.7% to 10.6% -cooking (15min) (Kmiecik et al., 2007): Ash : no reduction P : no reduction K: 39% reduction Ca: 14% reduction Mg: 11% reduction Fe: 22% reduction Zn: 14% reduction Mn: 13% reduction Cu: 18% reduction Cr: 43% reduction Ni: 17% reduction - cooking (9min after blanching and 12months frozen storage at -30°C) compared to fresh product (Kmiecik et al., 2007):

					Ash : 31% reduction P : 17% reduction K: 55% reduction Ca: 17% reduction Mg: 43% reduction Fe: 49% reduction Zn: 40% reduction Mn: 55% reduction Cu: 53% reduction Cr: 57% reduction Ni: 53% reduction -microwave heating (8min,15s after blanching and 12 months frozen storage at -30°C) compared to fresh product (Kmiecik et al., 2007): Ash : 10% increase P : 5% increase K: 35% reduction Ca: 11% reduction Mg: 9% reduction Fe: 17% reduction Zn: no reduction Mn: 10% reduction Cu: 20% reduction Cr: 43% reduction Ni: 27% reduction
Flavonoids	- storage 42days, 0°C, 84.8%RH in PVC: no significant change (Viňa et al.,2007a). - storage 42 days, 0°C, 84.8% RH in glycerol/starch-based coating and PVC: no significant change(Viňa et al.,2007a).	- blanching 1, 3 and 5 min in boiling water: no significant change (Viňa et al., 2007b). - preblanching 5min, 50°C followed by blanching 3 min, boiling water: decrease but not significant (Viňa et al., 2007b). - preblanching by microwave heating 5min, 700 W followed by blanching 2 min, boiling water: reduction but not significant (Viňa et al., 2007b).			

5.8 Corn (Zea Mays)

Nutrient	Fresh	Blanching	Freezing/ Frozen storage	Canning Jarring	Cooking Reheating
Ascorbic acid (vitamin C)					- Reduction at 115°C of 16,7, 25,0 and 45,8% for 10, 25 and 50 min heating respectively. - After heating at 100, 115 and 121°C for 25 min the vitamin C content dropped with 8,3, 25,0 and 41,7% respectively compared with raw unprocessed sweet corn (Dewanto et al., 2002).
Phenolic compounds			- Air-drying resulted in a 30% decrease in total phenolics in comparison to freezing and freeze-drying (Asami et al., 2003).		- increase at 115°C of 24,0, 32,0 and 36,0% for 10, 25 and min respectively. - After heating at 100, 115 and 121°C for 25 min the total free phenolic content increased with 16,0, 32,0 and 48,0% respectively compared with raw unprocessed sweet corn (Dewanto et al., 2002). - decrease in bound phenolic content across both heating time and heating temperature (Dewanto et al., 2002). -Lime cooking (100g lime in 30l water, 20min at 100°C and 12 h steeping) reduced total soluble phenols of for Mexican white corn for 90%. Further losses by tortilla/chip processing (stone grinded, baked 220°C, 1.5min and deep frying 175°C, 1min) of <2%; acidification (0.2g fumaric acid/100g dw) reduced losses with 3% (Del Pozzo-Insfran et al., 2007). - after lime cooking (100g lime in 30l water, until core temperature at 90°C) and 12 h steeping 61-78% reduction of total soluble phenols for Mexican and Amercian blue corn. Further losses by tortilla/chip processing (stone grinded, baked 220°C, 1.5min and deep frying 175°C, 1min) of 7 - 10%; acidification (0.2g fumaric acid/100g dw) reduced losses with 11% (Del Pozzo-Insfran et al., 2007).
Carotenoïds	*The major carotenoids in the principal brands of processed corn (canned corn, corn meal, corn flour, corn flake) and in typical corn dishes (farofa, boiled corn, pamonha, curau, fried and boiled polenta) were determined. There was marked variation between processed products and between brands of the same*				

	product, but variation between lots of the same brand was small. Canned corn had the highest zeaxanthin (11.91 to 18.06 mu g/g), beta-cryptoxanthin (2.32 to 3.77 mu g/g), and beta-carotene (1.79 to 2.75 mu g/g) contents. The corn flake breakfast cereal had the second highest amount of zeaxanthin (9.08 to 12.77 mu g/g). Corn meal had the highest lutein (4.02 to 7.62 mu g/g) level and also had good zeaxanthin content (6.13 to 11.39 mu g/g), but drastic reduction of all carotenoids, especially zeaxanthin, occurred when it was toasted to farofa. Boiled corn also had lower carotenoid levels compared to the raw corn. The wide variations in carotenoid concentrations appeared to be due mainly to varietal differences in the carotenoid composition of raw materials and to losses during processing and preparation for consumption (de Oliveira & Rodriguez-Amaya, 2007).				
antioxidants					- Lime cooking (100g lime in 30l water, 20min at 100°C and 12 h steeping) reduced antioxidant capacity of Mexican white corn for 25%. Further losses by tortilla/chip processing (stone grinded, baked 220°C; 1.5min and deep frying 175°C, 1min) of 26 and 46%; acidification (0.2g fumaric acid/100g dw) reduced losses by 12% (lime cooking, tortilla processing) and 6% (chip processing) (Del Pozzo-Insfran et al., 2007). - after lime cooking (100g lime in 30l water, until core temperature at 90°C) and 12 h steeping 42% reduction of antioxidants for Mexican and Amercian blue corn. Further losses by tortilla/chip processing (stone grinded, baked 220°C, 1.5min and deep frying 175°C, 1min) of 49% and 62%; acidification (0.2g fumaric acid/100g dw) reduced

					losses with 12% (lime cooking, tortilla processing) and 6% (chip processing) (Del Pozzo-Insfran et al., 2007).

5.10 Other vegetables

Zucchini (*Cucurbita pepo*)

In fresh zucchini, rutin was quantified as a marker for flavonoid glycosides. Cooking zucchini with a low volume (30ml) of water resulted in a decrease of rutin content of 21,1%, while cooking in a large volume (300ml) of water decreased the rutin content with 30,6% (Andlauer et al., 2003)

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BIBLIOGRAPHICAL STUDY
ON
THE NUTRITIONAL BENEFITS
OF PROCESSED FRUIT
& VEGETABLES

Addendum 2007
Tables fruits

8.1. Apple (Malus pumila)

Nutrient	Fresh	Cooking Reheating	Drying
Antioxidant capacity	- no changes during storage for 7 months at 1°C (Trierweiler et al., 2004) - 49-155% increase after 120 days at 0°C ; 120-140% increase after an additional storage of 7 days at 16°C (Leja et al., 2003) - 27.5-47.3% loss after 2 months at 2°C (Napolitano et al., 2004)	- Boiling 6-23 min: 91,5% retention (Agostini et al., 2004) - Steam cooking 3-22 min: 86,1% retention (Agostini et al., 2004) - Micro-waving 1,3-2,5 min: 66,4% (Agostini et al., 2004)	- Dry heat: 9-31 min: 49,4% retention (Agostini et al., 2004) - 561% increase compared to fresh fruits (Rababah et al., 2005) -
Vitamin C	- 25-30% loss after 6 months of conventional storage (Kalt, 2005) - no effect to 55% loss after storage for 7 months at 1°C, depending on the cultivar (Trierweiler et al., 2004)	- 36% and 42.6% loss after immersing apple cubes in water of 85°C and 95°C respectively and subsequent storage for 6 days at 4°C (Zuo et al., 2004)	
Phenolic compounds	- 26% loss after 6 months at 5°C (Kalt, 2005) - 0-15% increase after 120 days at 0°C ; 23-40% increase after an additional storage of 7 days at 16°C (Leja et al., 2003) - 91% decrease to 26% increase after storage for 2 months at 2°C, depending on cultivar (Napolitano et al., 2004)		- 153% increase compared to fresh products (Rababah et al. ,2005)
Anthocyanins	- 14-25% loss after 120 days at 0°C ; 20-28% loss after an additional storage of 7 days at 16°C (Leja et al., 2003) - 8.7% decrease after 120 days at 1°C (Maclean, 2006)		- 246% increase compared to fresh fruits (Rababah et al., 2005)
Flavonols	- no changes during storage at 1.5 and 4°C (Kalt, 2005) - no consistent effect of storage for 10 days at 1°C (Maclean, 2006)		

8.2. Cherry (Prunus avium)

Nutrient	Fresh	Freezing	Canning Jarring	Jam
Anthocyanins	- 41-52% decrease after storage for 15 days at 1°C (Esti et al., 2002) - 102-387% increase after storage for 6 days at 15°C; 131-240% after 30 days at 1-2°C (Gonçalves et al., 2004) - no change after 12 days at 2-4°C (Mozetic et al., 2006)	- 87% and 12% decrease after 6 months storage at -23°C and -70°C respectively (Chaovanalikit, 2004, 2004b)	- no effect after canning, but 11% and 38% decrease after subsequent storage for 5 months at 2°C and 22°C respectively (Chaovanalikit, 2004, 2004b)	- 14% retention after jam making (Kim, 2004)
Phenolic compounds	- 45-99% increase after storage for 6 days at 15°C; 6-43% after 30 days at 1-2°C (Gonçalves et al., 2004) - 16% decrease to 34% increase after storage for 6 days at 15°C, depending on cultivar; 20% decrease to 37% increase after storage for 30 days at 2°C (Gonçalves et al., 2004b)	- 50% decrease and 3% increase after 6 months storage at -23°C and -70°C respectively (Chaovanalikit, 2004, 2004b)	- 20% increase after canning, which was maintained after subsequent storage for 5 months at 2°C and 22°C (Chaovanalikit, 2004, 2004b)	- 54% retention after jam making (Kim, 2004)
Flavonols	- 45-82% increase after storage for 6 days at 15°C; 3-23% increase after 30 days at 1-2°C (Gonçalves et al., 2004)			
Antioxidative capacity	-51-85% decrease after storage for 6 days at 15°C; 9-96% decrease after 30 days at 1-2°C (Goncalves et al., 2004b)			
Vitamin C	- 75% loss after storage for 60 days at 1°C (Jiang et al., 2002) - 67% loss after 16 days at 30°C (40-50% RH); 87% loss after 30 days at 0°C (95-98% RH) (Yaman & Bayoindirli, 2002)			

8.3. Peach (Prunus persica)

Nutrient	Fresh	Washing Peeling Trimming	Freezing	Canning Jarring	Drying
Total phenolics	- 5% and 9% decrease after storage for 14 days at 4°C for peeled and unpeeled fruits respectively (Asami et al., 2003b) - 69% and 36% increase after storage for 24h at 30°C for peeled and unpeeled fruits respectively (Asami et al., 2003b)	- 13-48% loss, depending on the maturity of the fruit (Asami et al., 2003b)	- 52% and 18% increase after frozen storage of peeled peaches at -12°C for 1 and 3 months respectively; 43% and 5% increase for unpeeled peaches (Asami et al., 2003b)	- 0-21% loss, depending on the applied heat treatment; additional 30-40% decrease after subsequent storage for 3 months at ambient temperature (Asami et al., 2003b)	- 282% increase compared to fresh fruits(Rababah et al., 2005)
Anthocyanins					- 100% increase compared to fresh fruits (Rababah et al., 2005)
Antioxidant capacity					- 459% increase compared to fresh fruits (Rababah et al., 2005)

8.4. Raspberry (Rubus idaeus)

Nutrient	Fresh	Freezing	Cooking Reheating	Jam
Total phenolics	- 4% increase after 3 days at 4°C; 11% increase after an additional 24h at 18°C (Mullen et al., 2002)	- no effect after freezing to -30°C (Mullen et al., 2002)		- 64% retention after jam making (Kim, 2004)
Total anthocyanins	- 19% decrease after 9 days at 4°C, 40-73% decrease after 9 days at 20°C, 77-81% decrease after 9 days at 30°C (Suthanthangjai et al., 2005) - after 4 days at 20°C: 250% increase; after 7 days at 0°C and 4 days at 20°C: 160% increase; after 14 days at 0°C and 4 days at 20°C: 75% increase (Vicente et al., 2002)	- 21-25% reduction depending on freezing procedure (Sousa et al., 2005)	- heating (45°C-3h) : no effect immediately after treatment; heating + 4 days at 20°C: 80% increase; heating + 7days at 0°C + 4 days at 20°C: 140% increase; heating +14 days at 0°C + 4 days at 20°C: 32% increase (Vicente, 2002)	- 55% retention after jam making (Kim, 2004)
Vitamin E	- 23% decrease (trend but not significant) after storage for 2 weeks at 2°C (Han et al., 2004)			
Vitamin C	- 5% decrease after 3 days at 4°C; 7% increase after an additional 24h at 18°C (Mullen et al., 2002) - 10% decrease after 9 days at 1°C (Haffner et al., 2002)	- no effect after freezing to -30°C (Mullen et al., 2002)		
Antioxidative capacity	- no change after 3 days at 4°C and an additional 24h at 18°C (Mullen et al., 2002)	- no effect after freezing to -30°C (Mullen et al., 2002)		
Flavonols	- 13% increase after 3 days at 4°C; 6% increase after an additional 24h at 18°C (Mullen et al., 2002)	- 21% increase after freezing to -30°C (Mullen et al., 2002)		
Ellagic acid	- 83% increase after 3 days at 4°C; 5-fold increase after an additional 24h at 18°C (Mullen et al., 2002)	- 11% increase after freezing to -30°C (Mullen et al., 2002)		

8.5. Strawberry (Fragaria X ananassa)

Nutrient	Fresh	Freezing	Cooking Reheating	Drying	Jam
Antioxidant capacity	- 83%, 37% and very little increase after storage for 13 days at 10°C, 5°C and 3°C respectively (Ayala-Zavala et al., 2004) - 9-30% decrease after storage for 3 days at temperatures between 6°C and 25°C (Cordenunsi et al., 2005) - 15-66% decrease after 3 days at 4°C (Olsson et al., 2004)		- Boiling 6-23 min: 81,3% retention (Agostini et al., 2004) - Steam cooking 3-22 min: 82,0% retention (Agostini et al., 2004) - Micro-waving 1,3-2,5 min: 27,7% (Agostini et al., 2004)	- Dry heat: 9-31 min: 49,6% retention (Agostini et al., 2004) - convective drying + microwave-vacuum drying: 60% retention (Böhm et al., 2006) - freeze-drying: no reduction (Böhm et al., 2006) - 275% increase (Rababah et al. (2005)	
Vitamin C	- 55-70% loss after 4 days at 20°C (Kalt, 2005) - 10 days storage at 0°C: no significant effect on two cultivars, a 44% loss for another cultivar (Koyuncu, 2004) - 50% decrease after storage for 6 days at 6°C (Cordenunsi et al., 2003) - no significant changes after storage for 6 days at 6°C and 25°C, min. 30% increase at 16°C (Cordenunsi et al., 2005) - 15% increase after 3 days at 4°C (Olsson et al., 2004) - <5% loss, 6days at 5°C (Gil et al., 2006)	- no effect of frozen storage for 2 months at -20°C (Suutarinen et al., 2002) -15 days at -12°C, -18°C, -24°C: 64.5%, 10.7% , 8.9% loss respectively ; no effect of freezing method(Sahari et al., 2004)		- 56-64% loss after freeze-drying, 84-87% loss after air-drying (Asami et al., 2003) - convective drying + microwave-vacuum drying: 40% retention (Böhm et al., 2006) - freeze-drying: no reduction (Böhm et al., 2006)	- 13% retention after jam making, decreasing to 4% after jam storage for 4 months at 5°C (Suutarinen et al., 2002)
Total phenolics	- 56% retention of total phenolics after 8 days storage at 1°C (Nunes et al., 2005) - 57%, 30% and 0% increase after storage for 13 days at 10°C, 5°C and 3°C respectively (Ayala-Zavala et al., 2004) - no effect during storage for 6 days at temperatures from 6°C to room temperature (Cordenunsi et al., 2005) heating -2days at 20°C in		- heating 45°C, 3h in air + 2days at 20°C in darkness: 32% increase (Pan et al., 2004)	- 30-40% loss after freeze-drying, 37-44% loss after air-drying (Asami et al., 2003) - convective drying + microwave-vacuum drying: 35% retention (Böhm et al., 2006) - freeze-drying: no reduction (Böhm et al., 2006) - 213% increase (Rababah	

	darkness:no change (Pan et al., 2004)			et al., 2005)	

8.5. Strawberry (Fragaria X ananassa) Continued

Nutrient	Fresh	Freezing	Cooking Reheating	Drying	Jam
Carotenoids	- 10-15% loss, 6days at 5°C (Gil et al., 2006)				
Anthocyanins	- 57% retention of anthocyanins after 8 days storage at 1°C (Nunes et al., 2005) - 7.5% increase after 10 days at 10°C, 7.5% and 6% decrease after 5 days at 0°C and 5°C respectively (Ayala-Zavala et al., 2004) - between 20% increase and 27% decrease after storage for 6 days at 6°C, depending on the cultivar (Cordenunsi et al., 2003) - 40% to 10-fold increase after storage for 6 days, depending on storage temperature and cultivar (Cordenunsi et al., 2005) - 2 days at 20°C: 180% increase (Pan et al., 2004)	-quick freezing: 3 months at -12°C: 40.2% reduction; 3 months at -18°C and -24°C: 34.3% and 17.6% loss respectively ; Slow freezing: An increase of approximately 26%, 36% and 24% at resp. -12°C, -18°C and -24°C. (Sahari et al., 2004)	- heating 45°C, 3h in air + 2days at 20°C in darkness: 60% increase (Pan et al. 2004)	- 285% increase (Rababah et al., 2005)	- around 20% and 70% decrease in jam after storage for 3 months at 4°C and 20°C respectively (Wicklund et al., 2005)
Flavonols	- no effect during storage for 6 days at temperatures from 6°C to room temperature (Cordenunsi et al., 2005)				
Ellagic acid	- no significant change during storage for 6 days at temperatures between 6°C and 25°C (Cordenunsi et al., 2005)				
Vitamin E	- 26-59% loss (trend but not significant) after storage for 2 weeks at 2°C (Han et al., 2004)	- 22% loss (trend but not significant) after storage for 6 months at -23°C (Han et al., 2004)			
Vitamin B12	- storage at 4°C for 9 days: 99% retention; at 20°C: 62% retention (Strålsjö et al., 2003)				Retention 79-92% compared to fresh fruits (Strålsjö et al., 2003)

8.6. Other fruits

Apricot (*Prunus armeniaca*)

78% loss in vitamin C content after 12 days of storage at 25°C (Ayranci & Tunc, 2004)

Microwave drier for apricot drying is much effective than that in IR in terms of the speed of drying, preservation of original color of apricot samples and less losses of vitamins (A, C and E) and MDA values. It was observed that values of vitamins (A, C and E) andMDA in two apricot samples in different ripeness increase with decreasing moisture contents of samples. The values of vitamin (A and E) and MDA in the ripe apricot samples are larger than those in the near-ripe apricot samples throughout decreasing of moisture contents. However, values of vitamin C in the ripe apricot samples are less than those in the near-ripe apricot samples at all rates of moisture removals.The values of vitamins and MDA of apricot samples dried in microwave were found to be larger than those of samples dried in infrared drier (Karatas & Kamish, 2007)..

Marionberry (*Rubus spp.*)

No significant effect of freeze-drying on the total phenolics, 15.5-21.1% loss after air-drying (Asami et al., 2003)

Pear (*Pyrus communis*)

After storage for 14 days at 18-20°C, the vitamin C content decreased with 77% and 53% in the flesh and peel respectively (Galvis-Sanchez et al., 2006)

Mango (*Mangifera indica*)

Pasteurisation: (Vasquez-Caiceido et al., 2007)

Temperature (°C)	Holding time (min)	$P^{\circ}_{T_{ref}=93.3\,^{\circ}C}$ (min)	β-carotene				Vitamin A (RE/100 g FW)[c]
			Total[a] (μg/100 g FW)	all-*trans* (%)[b]	13-*cis* (%)	9-*cis* (%)	
85	0[d]	–	$361^{a,v} \pm 4.1$	78.0	13.4	8.7	$53.1^{a,v} \pm 0.6$
	1	0.34	$354^{a,v} \pm 4.4$	75.5	15.8	8.7	$51.5^{ab,v} \pm 0.6$
	4	0.76	$353^{a,v} \pm 3.4$	71.9	18.8	9.3	$50.3^{b,v} \pm 0.6$
	16	2.16	$336^{b,v} \pm 1.4$	66.4	22.3	11.4	$46.1^{c,v} \pm 0.2$
88	0	–	$359^{a,v} \pm 4.4$	78.4	13.2	8.4	$53.0^{a,v} \pm 0.8$
	1	0.88	$332^{a,w} \pm 3.5$	75.0	16.5	8.6	$48.1^{a,w} \pm 0.5$
	4	1.76	$324^{a,w} \pm 13.0$	72.1	18.8	9.1	$47.7^{b,w} \pm 0.7$
	16	4.71	$351^{a,v} \pm 16.6$	68.5	20.8	10.7	$48.9^{a,v} \pm 2.5$
90.5	0	–	$383^{a,v} \pm 0.7$	79.9	12.0	8.1	$57.0^{a,v} \pm 0.1$
	1	1.47	$362^{b,v} \pm 6.6$	74.1	17.2	8.7	$52.2^{b,v} \pm 1.0$
	4	2.59	$363^{b,v} \pm 0.2$	71.5	19.6	9.0	$51.5^{b,v} \pm 0.0$
	16	6.76	$356^{b,v} \pm 0.0$	64.1	23.4	12.4	$48.2^{c,v} \pm 0.1$
93	0	–	$349^{a,v} \pm 34.2$	78.8	13.1	8.1	$53.1^{a,v} \pm 4.0$
	1	2.09	$341^{a,v} \pm 2.6$	74.0	17.6	8.4	$49.1^{a,vw} \pm 0.5$
	4	4.41	$338^{a,vw} \pm 3.2$	68.8	21.7	9.5	$47.3^{a,w} \pm 0.4$
	16	14.91	$346^{a,v} \pm 0.2$	65.2	23.5	11.4	$47.2^{a,v} \pm 0.0$