Impact of non-thermal processing on plant metabolites

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Abstract

Non-thermal processes with cell membrane permeabilizing features such as high pressure treatment, high electric field pulse application, the use of supercritical carbon dioxide, or the subject to ultrasound in combination with moderate heat and pressure hold promise not only for gentle preservation but to also modify plant foods. Such modifications include the improvement of mass transfer and subsequent increases in juice yield, increased recovery as well as retention of desirable metabolites from plant materials, or enhanced water removal during dehydration operations. Such processes, specifically high electric field pulse treatment also allow the development of new processing concepts such as an “extraction free” beet sugar process, a low energy cell disintegration process for potato starch production or high pressure supported blanching.

Keywords: Food processing; Non-thermal processing; High pressure; High electric field pulse; Plant metabolites; Ultrasound; Supercritical carbon dioxide

1. Introduction

During the last 15 years intensive research and development activities have been carried out regarding gentle (in German: 'schönende') food preservation methods (Gould, 1995) especially high hydrostatic pressure (Hendrickx & Knorr, 2002) and on high intensity pulsed electric fields (High intensity electric field pulse treatment of foods, 2001).

The recent emphasis of health related, functional foods and food ingredients and the integration of food production, food processing and preservation and of nutritional aspects (Bellisle et al., 1998), as well as the re-emergence of efforts in the area of sustainable food systems (Knorr, 1983) has led to renewed interest in the production, retention and availability of desirable plant metabolites.

One of our ongoing research strategies concentrates on the processing related retention and availability of plant metabolites. The emphasis of this publication is on the impact of cell membrane permeabilizing methods on specific plant metabolites and on metabolite driven process improvements.

2. Comparison of permeabilizing methods

Although all four processing methods discussed below have cell membrane permeabilizing features, their principles of action differ as outlined in Table 1.

A comparison of various non-thermal pretreatment methods of blue grapes prior to expression (Fig. 1) revealed improved juice yields for all treatments as compared to the untreated controls. The juice yield of the high pressure treated samples was comparable to the commercial enzyme treated one.

When the anthocyanine concentrations of the resulting juices were compared significant increases were also observed for the non-thermal, physical treatments (Fig. 2) with high pressure treatment resulting in higher levels than the enzyme treated samples.

One of the key advantages of physical pretreatment methods as compared to enzyme treatment is the similarity of juice quality criteria to the untreated (freshly squeezed) juice as exemplified in Fig. 3. Similar results regarding the impact of electric field pulse treatments on grape juice yields and quality have been reported previously (Eshtiaghi & Knorr, 2000).

Non-thermal pretreatments (high hydrostatic pressure (HP), high intensity electric field pulses (HELP), supercritical carbon dioxide (ScCO₂)) were also evaluated with respect to fermentation kinetics and quality criteria of the resulting products (Eshtiaghi & Knorr, 2001a).
Differently pretreated red paprika stripes resulting in the same average degree of permeabilization of $Z_p = 0.45–0.49$ (Angersbach, Heinz, & Knorr, 2000) were subjected to fermentation with *Lactobacillus plantarum*.

As evident from data in Fig. 4 microbial counts of most pretreated samples reached a maximum already after four days (five for HP treatment), while the untreated ones needed six days to reach their peak.

Similar increase in microbial counts could be obtained after HELP treatment of red beet samples (Fig. 5).

Quality criteria such as texture parameters were retained during fermentation to a much higher extent as those of the untreated controls (Fig. 6).

### 3. Process developments based on high intensity electric field pulse technology

Pilot scale to industrial scale processes involving the application of high electric field pulses under development in our laboratory include sugar beet processing (Eshtiaghi & Knorr, 1999; Eshtiaghi & Knorr, 2001b)
with the potential to make high temperature extraction processes obsolete or to even replace them by expression or centrifugation steps; potato starch processing to increase starch yields and to reduce waste effluent loads (Angersbach, 2001); and the treatment of sludge for sanitation and microbial sanitation purposes (Heinz, 2001).

Pulsed electric fields have been applied successfully prior to osmotic dehydration of carrots (Rastogi, Eshtiaghi, & Knorr, 1999) and bell peppers (Ade-Omowaye, Rastogi, Angersbach, & Knorr, 2002).

A comparison of electric field pulse treatments prior to different dehydration methods (Fig. 7) clearly indicated that the pretreatments led to substantial...
reductions of drying times of grapes, plums and asparagus (Tedjo et al., 2002) as exemplified for grapes in Fig. 7.

It is essential to also note that the rehydration properties of the HELP pretreated and differently dried products correlate with their rehydration properties suggesting that HELP assisted improved drying rates also resulted in reduced dehydration times (Fig. 8).

4. Conclusions

Current research activities using non-thermal pretreatment methods also concentrate on the optimization of agronomic factors for plant foods (e.g., asparagus) and to adopt subsequent processing techniques for the improvement of retention and availability of nutritionally relevant metabolites, on optimizing the selective release of desirable microbial and plant metabolites, on the physical modification of plant metabolites and on the increase in mass transfer of functional ingredients. Further, activities are carried out to investigate and enhance the secondary metabolite production of cultured plant cells as model systems for real foods by controlled pretreatment with non-thermal processes (e.g., electric field pulses) in continuous reactors. It is hoped that this brief exploratory synopsis into the field of non-thermal processing and how it relates to metabolic production from plants allows an insight into the—what we believe—tremendous potential of improving our future food supply with enhanced functional constituents based on an intelligent controlled and responsible use of currently available non-thermal preprocessing technologies.

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