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## Processing and storage of innovative pasty parsley (*Petroselinum crispum* (MILL.) NYM EX A. W. HILL) and celeriac (*Apium graveolens* L. var. *rapaceum* (MILL.) DC.) products

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### Summary

A process for the production of innovative pasty parsley and celeriac products was developed. Freshly harvested plant material was blanched, processed into a paste, and subsequently heated for 3 min at 90 and 95 °C, respectively. Chlorophyll stability was not affected by the thermal process due to the addition of 0.05 % (m/v) MgCl<sub>2</sub> to the blanching water. In all products, the contents of the main phenolic compound apiin decreased, while those of the minor compound malonylapiin B increased. In parsley pastes, peroxidase (POD) and polyphenol oxidase (PPO) were fully inactivated by the heat treatment. In contrast, only complete PPO inactivation was achieved in celeriac pastes. However, since POD inactivation was incomplete, its partial reactivation during storage of celeriac pastes was observed. After 4 weeks of cold storage, the green color of the parsley pastes turned into an olive hue due to chlorophyll degradation. Nevertheless, the products may be stored at -20 °C for several months. In contrast, storage of celeriac pastes at 4 and -20 °C is possible for several months without darkening. Compared to conventional dried herbs and spices the products obtained by the innovative process are characterized by bright colors. Pasty products are easier to handle, because lumping and dusting are avoided, thus facilitating their safe application in the food processing industry.

### Introduction

Conventional herbs and spices are natural products therefore being commonly burdened with high microbial loads. Furthermore, most spices are produced in tropical and subtropical countries under poor hygienic conditions. In particular, drying of the raw material is often performed by spreading the plant material on the ground without protection from animals. The hot and humid climate and often lacking risk awareness of the farmers may result in considerable hygienic and sensory problems, causing an increased number of food-borne infections and intoxications. Although dried spices are microbiologically stable due to their low water activities, microbial populations may develop quickly after their rehydration in high-moisture foods. Upon drying of herbs and spices deteriorative enzymes, such as peroxidases, polyphenol oxidases, proteinases, and chlorophyllases, are only inhibited, without being inactivated. During storage of spices and upon rehydration of dried foods, such enzymes may regain their activity and adversely affect color, taste, and texture properties of the food products (SCHWEIGGERT et al., 2007).

Color is a decisive quality attribute of vegetable products. Chlorophylls are the predominant pigments of green plants (SCHWARTZ and LORENZO, 1990), and the bright green color is associated with freshness of herbs like parsley (*Petroselinum crispum* (MILL.) NYM EX A. W. HILL), while discoloration may lead to consumers' rejection (LANFER MARQUEZ and SINNECKER, 2008). Chlorophyll degradation is mainly responsible for changes or loss of color. Heating results in the conversion of green chlorophylls a and b into their corresponding olive brown pheophytins due to the replacement of the Mg atom by

hydrogen (SCHWARTZ and LORENZO, 1990; MACKINNEY and WEAST, 1940). During storage chlorophyll degradation is catalyzed by chlorophyllase (EC 3.1.1.14) and magnesium dechelataase. While chlorophyllase activity cleaves the phytol moiety, yielding water-soluble chlorophyllides, the removal of the central Mg atom is accomplished by the magnesium dechelataase (KIDMOSE et al., 2002; MATILE et al., 1999).

Brown discoloration of celeriac (*Apium graveolens* L. var. *rapaceum* (MILL.) DC.) has a negative impact on consumers' acceptance. Peroxidases (POD; EC 1.11.1.7) and polyphenol oxidases (PPO; EC 1.14.18.1, EC 1.10.3.2) play an important role in this process. Due to decartmentalization of individual cells, phenolic compounds and enzymes are released resulting in colored complexes, the so-called melanins (TOMÁS-BARBERÁN and ESPÍN, 2001). Since POD is the most heat stable enzyme, it has been the most common indicator of enzyme inactivation in the blanching process (VAMOS-VIGYÁZÓ, 1981). Consequently, for color stabilization, the immediate and complete inactivation of deteriorative enzymes is a prerequisite.

To overcome the above-mentioned problems associated with conventional spice production, an alternative process for the production of high quality spices has recently been developed. For this purpose, the fresh plant materials (green pepper, ginger, chili, coriander and paprika) were minced and subsequently heated. In some cases, blanching prior to grinding has been shown to be advantageous. Compared to conventional spices, the so obtained spice powders were characterized by brighter colors and significantly lower microbial loads due to the immediate thermal inactivation of deteriorative enzymes and reduction of microorganisms, respectively (SCHWEIGGERT et al., 2005a, b).

Conventional herbs and spices exhibit poor sensory properties. Furthermore, they are difficult to handle and dose in industrial food processing due to lump and dust formation. Therefore, the development of pasty herb and spice products should be advantageous. In recent years, the demand for spice pastes has considerably increased. However, for the production of red and green chili, ginger, and coriander leaf pastes salt, organic acids, and hydrocolloids are commonly added to preserve the products (BARANOWSKI, 1985; AHMED et al., 2002, 2004).

Our previous studies have demonstrated blanching to be recommended as initial step for the production of pasty herb and spice products. Short-time blanching resulted in the inactivation of POD and PPO, and improved color stability of parsley and celeriac (KAISER et al., 2012, 2013b). Furthermore, phenolic compounds were better retained upon blanching of parsley, marjoram, celeriac, coriander leaves and fruits (KAISER et al., 2013a, b, c). The objective of the current study was to cover the entire innovative process for the production of pasty herb and spice products exemplified for parsley and celeriac. In particular, the addition of magnesium to the blanching water should avoid its leaching, and thus improve chlorophyll stability. Furthermore, the impact of processing and storage conditions on color stability, chlorophyll and polyphenol retention as well as enzyme activities of innovative pasty parsley and celeriac products should be evaluated.

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## Materials and methods

### Raw material

Flat-leaved parsley (*Petroselinum crispum* (MILL.) NYM EX A.W. HILL cv. 'Gigante d'Italia') and celeriac (*Apium graveolens* L. var. *rapaceum* (MILL.) DC. cv. 'Goliath') were cultivated in 2011 by Pharmaplant Arznei- und Gewürzpflanzen Forschungs- und Saatzucht (Artern, Germany). The fresh plant materials were processed into pastes directly after harvest.

### Chemicals

Reagents and solvents were purchased from VWR (Darmstadt, Germany) and were of analytical or HPLC grade. Apigenin-7-O-apiosylglucoside was from Carl Roth (Karlsruhe, Germany). Deionized water was used throughout.

### Process for the production of pasty herb and spice products

#### Parsley

Amounts of 10 kg of freshly harvested parsley leaves were washed with tap water and blanched at 100 °C for 1 min in a water bath containing 0.05 % (m/v) MgCl<sub>2</sub>. The blanched material was subsequently cooled in ice-water, drained and minced for 3 min in a bowl chopper (MADO Garant, Dornhan, Germany). The resulting products were immediately heated in a hermetically sealed 3 L pilot-plant scale Type EL 3 reaction vessel (ESCO-Labor, Riehen, Switzerland) under stirring at 90 and 95 °C, respectively, for 3 min. Set temperatures were achieved after approximately 3 min. After heat treatment the pasty products were cooled to 25 °C.

#### Celeriac

Amounts of 15 kg of washed celeriac were manually peeled, quickly cut into 1 cm slices, and subsequently steam-blanched at 100 °C for 5 min using a stainless steel vessel. After cooling in ice-water the blanched material was minced using a grater (Bucher-Guyer, Niederweningen, Switzerland) prior to fine comminution in a K60 colloid mill (Probst & Class, Rastatt, Germany) with an aperture size of 50 µm. The resulting product was heated in the reaction vessel as described above for parsley applying the same processing conditions.

Unheated control samples were prepared without heating, solely by mincing parsley and celeriac, respectively, as described above.

### Storage of pasty parsley and celeriac products

Aliquots of 100 g of the products were filled into polyethylene bags under reduced pressure. Samples were stored at 4 and -20 °C in the dark for 12 weeks.

### Determination of chlorophylls

Extraction and quantitation of chlorophylls and their degradation products were performed as earlier described (KAISER et al., 2012).

### Determination of phenolic compounds

Polyphenol analyses were carried out as previously reported (KAISER et al., 2013a, b).

### Determination of POD and PPO

POD and PPO activities were determined as earlier reported (KAISER et al., 2012, 2013b).

### Color measurement

Color measurements were performed using a CR-300 chroma meter (Minolta, Osaka, Japan) as previously described (KAISER et al., 2012) and expressed as  $L^*$ ,  $a^*$ ,  $b^*$ ,  $h^\circ$  and  $C^*$  values.

### Determination of dry matter (DM) contents

Lyophilization of the samples was carried out using a freeze-dryer (Lyovac GT4 AMSCO Finn-Aqua, Hürth, Germany) for 72 h. Prior to and after freeze-drying sample weights were measured and subsequently dry matter contents were calculated.

### Statistical analysis

Tukey test, using the SAS software package (SAS Institute, Cary, NC, USA; v. 9.1), was performed to determine significant differences ( $\alpha = 0.05$ ) between independent samples.

## Results and discussion

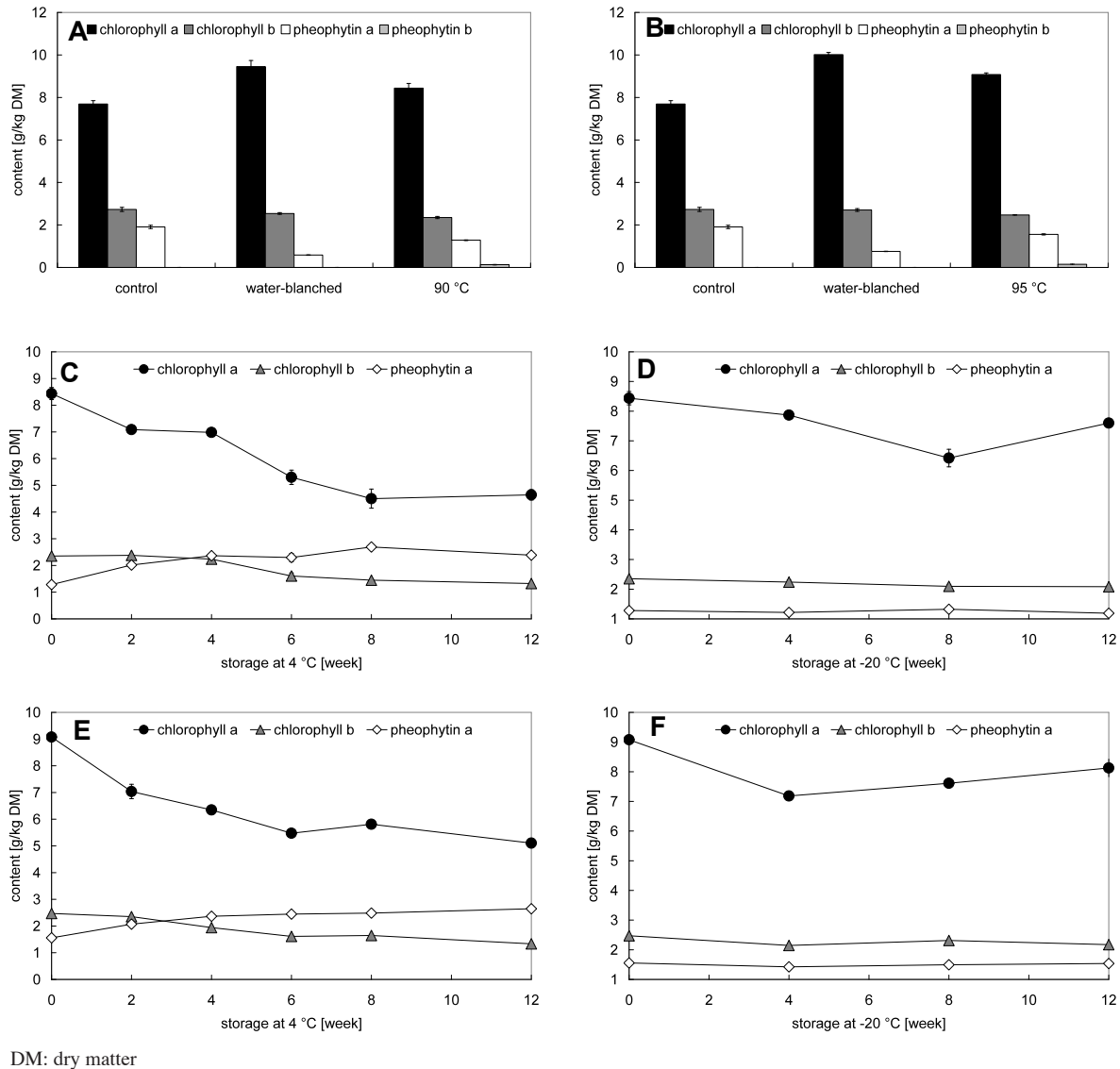
### Impact of processing on the quality of pasty parsley and celeriac products

Pasty parsley and celeriac products were processed by blanching the washed plant material to inactivate endogenous quality deteriorating enzymes, thus enhancing color retention. Subsequently, for preservation, the pasty products were heated at 90 and 95 °C, respectively, for 3 min.

### Chlorophylls

The profile of chlorophylls and chlorophyll degradation products in parsley has been reported in our previous study (KAISER et al., 2012). Chlorophyll a and b represented the major compounds in the unheated control. In the sample investigated in the present study, the pheophytin a content was unexpectedly high (Fig. 1A, B). Release of acids from the vacuoles was enhanced due to decompartmentalization of individual cells resulting from mincing, thus probably provoking the formation of this magnesium-depleted derivative. Furthermore, the replacement of the central magnesium atom by two protons may be catalyzed by magnesium dechelataase (KIDMOSE et al., 2002).

Compared to the unheated control, chlorophyll a contents were significantly higher in water-blanched samples (Fig. 1A, B). Preliminary tests have shown that the magnesium content in water-blanched parsley after the addition of magnesium to the blanching water was higher than in unheated parsley. In contrast, the magnesium content decreased upon water-blanching without magnesium addition (data not shown). Consequently, in the present study, magnesium leaching was prevented resulting in enhanced chlorophyll retention. Furthermore, heating enhances the disruption of plant cells and tissues leading to an improved release, and thus better extraction of chlorophyll a, which may also contribute to higher contents upon blanching (JIMÉNEZ-MONREAL et al., 2009). In contrast, following heat treatment, chlorophyll b contents did not significantly change. Water-blanching resulted in a significant decrease of pheophytin a contents, probably due to less leaching because of magnesium addition to the blanching water. However, subsequent heating at 90 and 95 °C, respectively, led to chlorophyll degradation to the corresponding pheophytins, since chlorophyll a and b contents tended to decrease, while pheophytin a and b contents significantly increased. Pheophytin b was only detected in parsley pastes heated at 90 and 95 °C, respectively, indicating that chlorophyll a is more susceptible to form pheophytin than chlorophyll b, which is in agreement with a previous report (TAN and FRANCIS, 1962).



**Fig. 1:** Chlorophyll and pheophytin contents during processing (A, B) and 12 weeks of storage (C-F) at 4 and -20 °C of parsley pastes: (A) processing at 90 °C, (B) processing at 95 °C, (C) storage at 4 °C of the pastes processed at 90 °C, (D) storage at -20 °C of the pastes processed at 90 °C, (E) storage at 4 °C of the pastes processed at 95 °C, (F) storage at -20 °C of the pastes processed at 95 °C. Columns and bars represent mean  $\pm$  standard deviation (n = 2).

In our previous study, heating of minced parsley resulted in a marked degradation of chlorophylls (KAISER et al., 2012). The results of the present study showed that the blanching step and the addition of magnesium to blanching prior to mincing and subsequent heating are indispensable for chlorophyll retention. Similar findings irrespective of magnesium addition were reported for dried marjoram, rosemary (SINGH et al., 1996), mint, and basil (ROCHA et al., 1993) which were blanched prior to drying. In the present study, retention of chlorophylls in the parsley pastes obtained was improved compared to air-dried and freeze-dried basil leaves, where chlorophyll losses could not be avoided (DI CESARE et al., 2003).

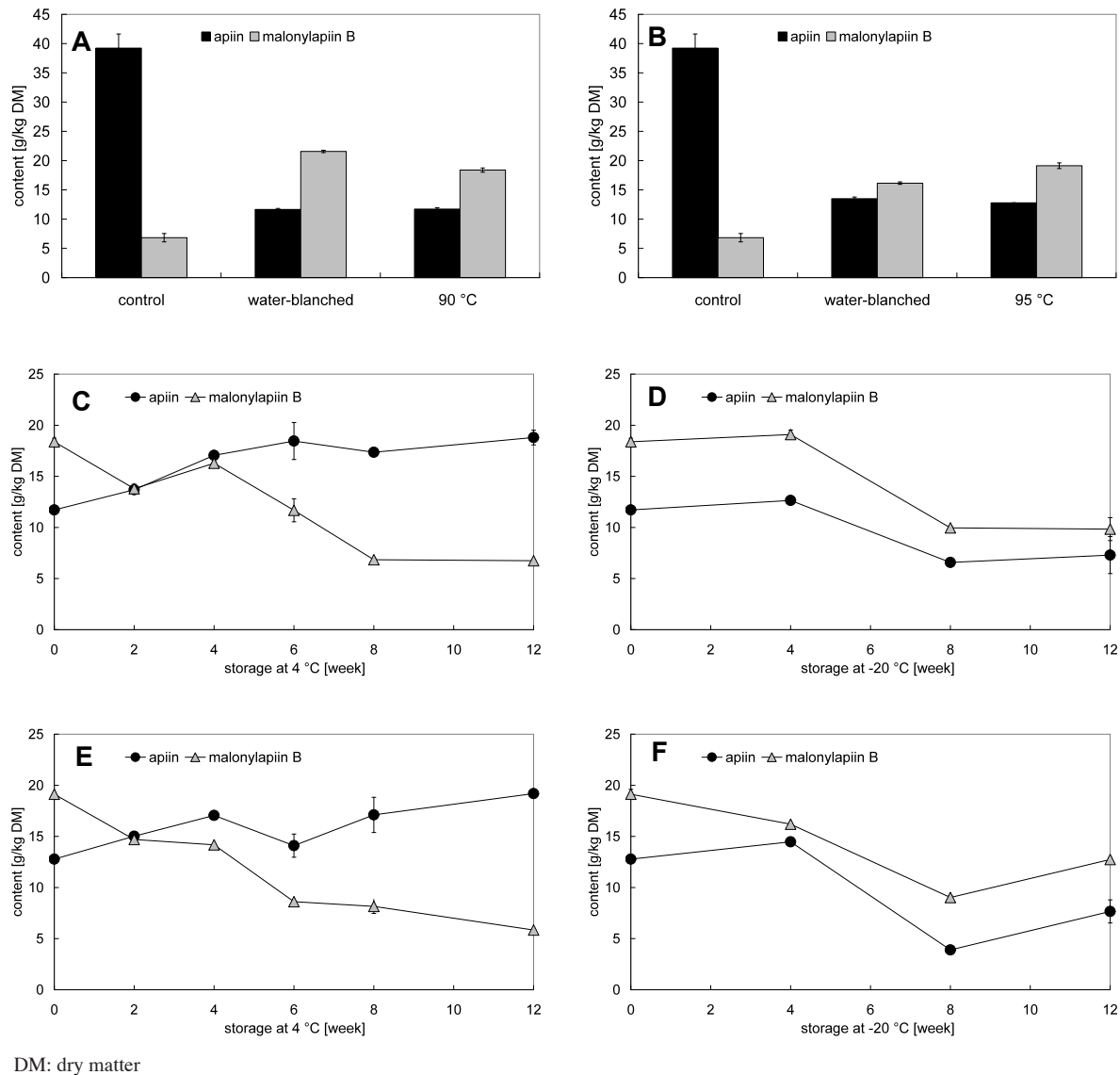
### Phenolic compounds

In accordance with our previous reports (KAISER et al., 2013a, b), apiin (apigenin-7-*O*-apiosylglucoside) was found to be the major phenolic compound both in unheated parsley and celeriac. In contrast, malonylapiin B turned out to be the predominant compound in

blanched parsley and celeriac, since apiin contents decreased upon water-blanching of parsley and steam-blanching of celeriac, while malonylapiin B contents increased (Fig. 2A, B; 3A, B). The latter may probably be due to enhanced extractability. Therefore, only these two compounds were considered in the present investigation of polyphenol stability. Compared to blanched parsley, apiin and malonylapiin B contents remained virtually unchanged in pasty parsley products independent of the heating temperature applied. In contrast, heating of the pasty celeriac products resulted in a decrease of apiin contents and an increase of malonylapiin B contents.

### POD and PPO activities

Initial POD and PPO activities of parsley were  $687.7 \pm 21.9$  and  $17.5 \pm 1.0$  nkat/g DM, respectively. Residual POD activities ranged from 1.6 to 1.9 % after processing of pasty parsley products, coming close to complete inactivation. In contrast, PPO activity was completely ceased upon water-blanching.

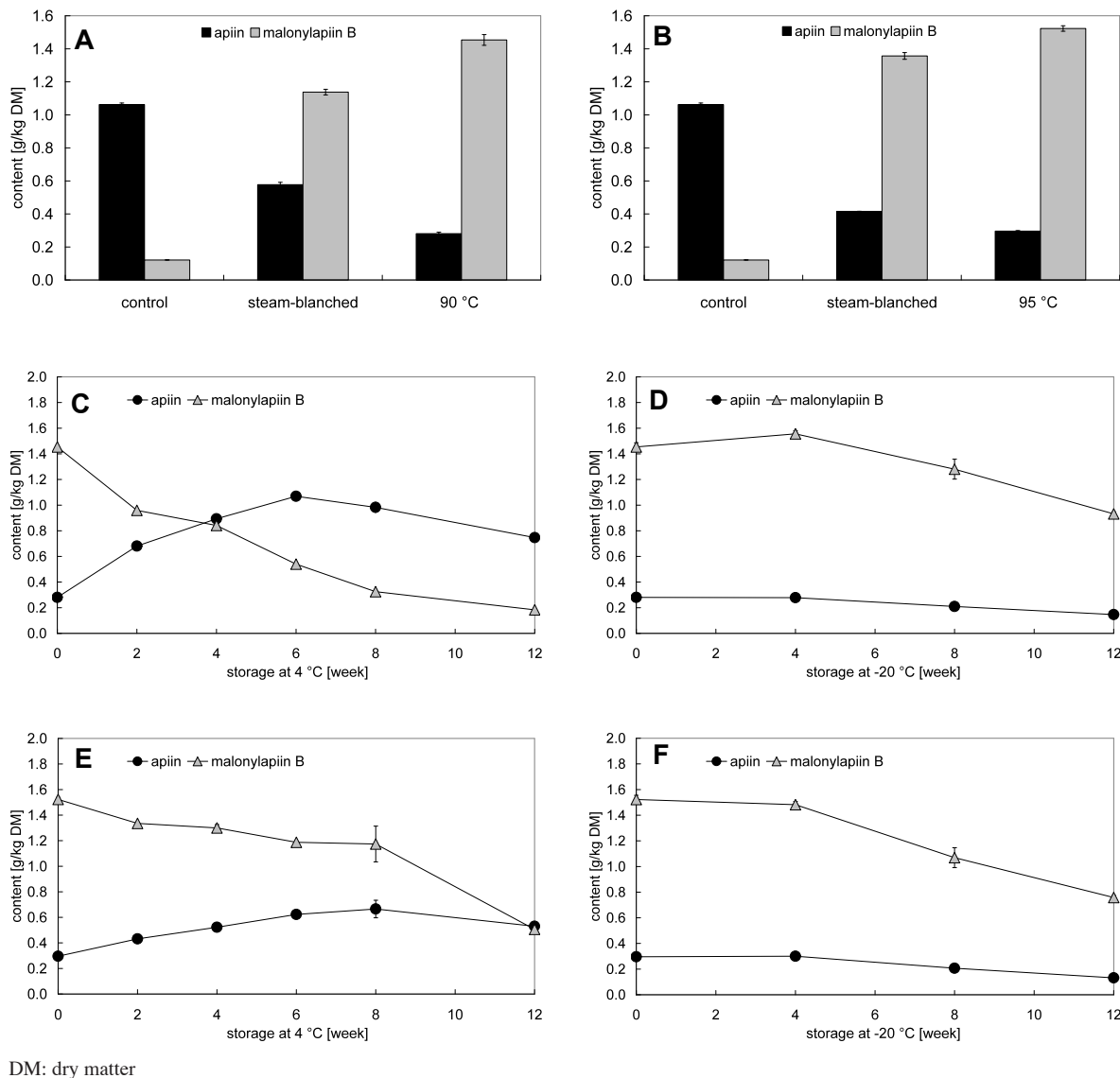


**Fig. 2:** Apiin and malonylapiin B contents during processing (A, B) and 12 weeks of storage (C-F) at 4 and -20 °C of parsley pastes: (A) processing at 90 °C, (B) processing at 95 °C, (C) storage at 4 °C of the pastes processed at 90 °C, (D) storage at -20 °C of the pastes processed at 90 °C, (E) storage at 4 °C of the pastes processed at 95 °C, (F) storage at -20 °C of the pastes processed at 95 °C. Columns and bars represent mean  $\pm$  standard deviation ( $n = 2$ ).

In unheated celeriac, POD and PPO activities amounted to  $30.0 \pm 2.1$  and  $47.7 \pm 2.9$  nkat/g DM, respectively. After steam-blanching, POD activity was not detectable. However, in the pastes heated at 90 and 95 °C, respectively, high residual POD activities, reaching 52 and 50 % of their initial values, respectively, were determined. It is supposed that the extraction of POD from the complex plant matrix was enhanced as a result of thermal degradation of cell walls and subcellular compartments (JIMÉNEZ-MONREAL et al., 2009). Furthermore, as previously hypothesized, during heating a novel compound exerting higher thermostability may have been formed from the heat-denatured enzyme protein comprising groups of POD which are still active (WINTER, 1971). However, absolute POD activities were very low. Despite the presence of POD activities, enzymatic browning of the products was not observed. PPO was completely inactivated during processing suggesting enzymatic browning of celeriac to be mainly due to PPO activity as previously stated (KAISER et al., 2013b).

### Color

Water-blanching parsley exhibited significantly lower  $a^*$  values (greenness) and higher  $b^*$  values (yellowness) compared to the unheated control (Tab. 1). Consequently, hue angles were higher, indicating a more intense green hue. Due to blanching, tissue softening and release of intercellular air and dissolved gases may have influenced surface reflectance and depth of light penetration into tissues resulting in color enhancement (BREWER et al., 1994). In our previous study, mincing prior to heating resulted in olive-green color of the products due to chlorophyll degradation (KAISER et al., 2012). In the present study, after mincing and heating at 90 and 95 °C, respectively, hue angle was comparable with that of the unheated sample which was attributed to enhanced chlorophyll retention as a result of the blanching step supported by magnesium addition. Previous reports have shown that blanching prior to drying had a positive effect on color retention of marjoram and rosemary as compared to direct drying (SINGH et al., 1996). In contrast, significant color changes



**Fig. 3:** Apiin and malonylapiin B contents during processing (A, B) and 12 weeks of storage (C-F) at 4 and -20 °C of celeriac pastes: (A) processing at 90 °C, (B) processing at 95 °C, (C) storage at 4 °C of the pastes processed at 90 °C, (D) storage at -20 °C of the pastes processed at 90 °C, (E) storage at 4 °C of the pastes processed at 95 °C, (F) storage at -20 °C of the pastes processed at 95 °C. Columns and bars represent mean ± standard deviation (n = 2).

were not observed after microwave drying of fresh parsley compared to fresh plant material (SOYSAL, 2004).

Unheated minced celeriac showed a brown color, which is ascribed to enzymatic browning as a result of decompartmentalization of individual cells (TOMÁS-BARBERÁN and ESPÍN, 2001). After processing of celeriac pastes, lightness  $L^*$  significantly increased, while chroma  $C^*$  decreased, and  $h^o$  values shifted towards more yellowish hues (Tab. 2). Consequently, the pastes obtained were characterized by a perfect white color. In agreement with our findings, a blanching step prior to air and vacuum drying, respectively, also resulted in light colored celeriac products (ALIBAŞ, 2012).

**Impact of storage on the quality of pasty parsley and celeriac products**

To evaluate the storage stability of the pastes, the processed products were stored for 3 months in the dark at 4 and -20 °C. Quality

of the pastes was monitored considering the same parameters as for processing.

**Chlorophylls**

As can be seen from Fig. 1C-F, chlorophylls in parsley pastes were differently affected by various storage temperatures. During storage chlorophyll a degradation was stronger than that of chlorophyll b resulting in a marked formation of pheophytin a as reported in previous studies (SCHWARTZ and LORENZO, 1991). In pastes heated at 90 °C, chlorophyll a and b contents first significantly decreased after 6 weeks of cold storage which was accompanied by an increase of pheophytin a contents. In contrast, in the products processed at 95 °C, degradation of chlorophyll a already started after the first two weeks going along with a rise of pheophytin a contents, and chlorophyll b degradation was first observed after 4 weeks of cold storage. This indicated higher processing temperatures to cause a more pronounced



destruction of cells, thus resulting in earlier chlorophyll degradation. During storage of both parsley products, pheophytin b contents were rather low amounting to 0.09-0.44 g/kg DM. As expected, chlorophyll degradation was more pronounced at 4 °C than at -20 °C, since low storage temperatures preserve chlorophylls (LANFER MARQUEZ and SINNECKER, 2008). In both parsley pastes stored at -20 °C, a slight decrease of chlorophyll a contents was observed, while chlorophyll b and pheophytin contents virtually did not change.

In parsley pastes, losses during cold storage for 3 months were in the range of 44-45 % and 44-46 % for chlorophyll a and b, respectively. In contrast, in products stored at -20 °C losses amounted to 10-11 % and 11-12 % for chlorophyll a and b, respectively. In literature, different findings concerning chlorophyll degradation during storage of green herbs and vegetables were reported. When water-blanching parsley was stored at -20 and -30 °C, chlorophyll losses were insignificant (LISIEWSKA and KMIĘCIK, 1997). In contrast, during frozen storage at -18 °C of blanched peas and green beans for 12 and 9 months, respectively, degradation of chlorophyll was observed (GÖKMEK et al., 2005; BAĞÇECİ et al., 2005). In blanched dill stored at -20 °C for 12 months chlorophyll losses of 9 % and 15 % for leaves and whole plants, respectively, were determined; however, during storage at -30 °C for 12 months, chlorophyll contents did not change (LISIEWSKA et al., 2004).

### Phenolic compounds

The phenolic contents showed similar trends during storage at 4 and -20 °C for both parsley products (Fig. 2C-F). During storage at 4 °C, apiin contents tended to increase, while malonylapiin contents significantly decreased. Storage at -20 °C resulted in a decrease of apiin and malonylapiin B contents. It is supposed that a malonyl esterase has not completely been inactivated, thus being responsible for the degradation of malonylapiin to apiin, since malonyl esterase activity in parsley has previously been described (MATERN, 1983). As expected, this reaction was enhanced at 4 °C compared to storage at -20 °C.

In celeriac products heated at 90 °C, apiin contents significantly increased during cold storage (Fig. 3C). In contrast, malonylapiin B contents markedly declined. In pastes heated at 95 °C, a significant decrease of malonylapiin B contents was first observed after 12 weeks of storage at 4 °C (Fig. 3E). Apiin contents significantly increased after four weeks and then remained unchanged. Storage at -20 °C did not affect apiin contents (Fig. 3D, F). In contrast, malonylapiin B contents significantly decreased. Although malonyl esterase activities in celery and celeriac, respectively, have so far not been reported, this enzyme is assumed to occur also in celeriac, causing the observed degradation of malonylapiin.

### POD and PPO activities

Although regeneration of POD and PPO activities during storage has previously been reported for spices, vegetables, and fruits (SCHWEIGERT et al., 2006; THONGSOOK and BARRETT, 2005; HOLZWARTH et al., 2012), in the present study, POD and PPO did not regain their activities during storage of parsley products. In contrast, regeneration of POD was observed in both celeriac products, probably due to incomplete inactivation during heat treatment (Fig. 4). Nevertheless, the POD activities determined were only marginal, while PPO activity was not detected during storage. Thus, enzymatic browning of the celeriac products was inhibited. These findings support our assumption that mainly PPO is responsible for enzymatic browning of celeriac.

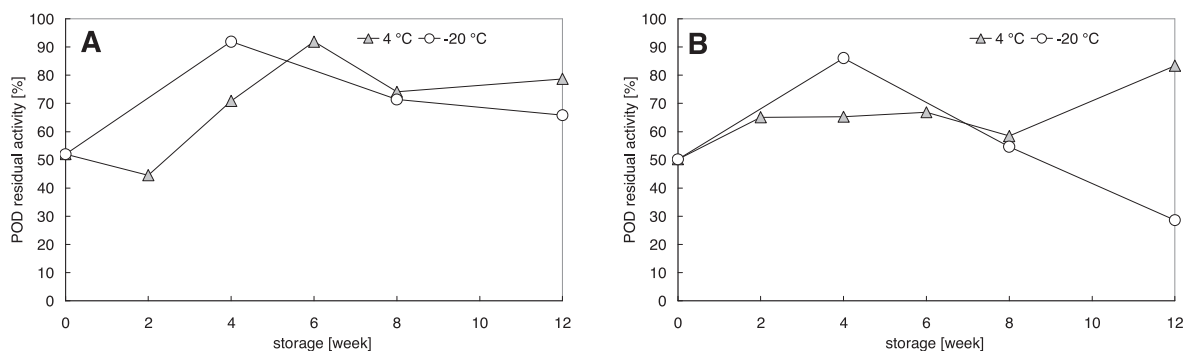
### Color

Independent of processing time, color characteristics of both parsley products showed similar trends during storage (Tab. 1). During 12 weeks of storage at 4 °C,  $h^{\circ}$  values declined markedly, corresponding to a shift to yellowish tones. This observation goes along with major chlorophyll losses resulting in a decline of  $a^*$  values. Consequently, the green color turned into olive due to pheophytin formation. In contrast, hue angles only slightly increased during storage at -20 °C due to better chlorophyll retention. Even though the  $h^{\circ}$  values of the products stored at -20 °C were significantly lower at the end of storage than that of the unheated control, the parsley products were characterized by a bright green color. Yellowness did not significantly change during storage at 4 and -20 °C.

The color values of the celeriac pastes remained virtually unchanged at both storage temperatures (Tab. 2). Thus, the products retained their white color. Enzymatic browning was prevented by complete PPO inactivation during processing of the pastes.

### Conclusions

In the present study, a process for the production of innovative pasty parsley and celeriac products possessing improved color was established. After blanching the plant material was converted into a paste and subsequently heated. Compared to conventional dried herbs and spices, the so obtained pasty products are characterized by bright colors. This may be attributed to enhanced chlorophyll retention in parsley partly due to the prevention of magnesium leaching and the early PPO inactivation in celeriac, respectively, as a result of the initial heating step. Complete inactivation of POD celeriac could not be achieved; however, its activities were negligible. The contents of the main phenolic compound apiin strongly decreased, while the minor compound malonylapiin B significantly increased, when processing



**Fig. 4:** Residual POD activities during 12 weeks of storage of celeriac pastes, processed at 90 °C (A) and 95 °C (B). Residual POD activities based on the initial POD activity in unheated celeriac.

**Tab. 1:** Color characteristics during processing (90 and 95 °C) and storage (12 weeks at 4 and -20 °C) of pasty parsley products (n = 6)

Process parameter	90 °C			95 °C		
	<i>a</i> *	<i>b</i> *	<i>h</i> °	<i>a</i> *	<i>b</i> *	<i>h</i> °
Control (unheated)	-6.6 ± 0.9 e	9.8 ± 0.8 e	123.7 ± 1.6 bc	-6.6 ± 0.9 e	9.8 ± 0.8 d	123.7 ± 1.6 b
Water-blanching	-12.3 ± 0.4 i	13.5 ± 1.0 a	132.3 ± 1.2 a	-11.3 ± 0.5 h	12.8 ± 0.7 ab	131.4 ± 0.8 a
After processing, week 0	-9.2 ± 0.3 h	13.1 ± 0.8 ab	125.1 ± 0.8 b	-8.2 ± 0.3 g	11.9 ± 0.5 abc	124.3 ± 0.3 b
Week 2, 4 °C	-5.4 ± 0.3 d	13.5 ± 0.3 a	111.7 ± 0.7 f	-5.1 ± 0.2 d	13.0 ± 0.5 a	111.5 ± 0.3 e
Week 4, 4 °C	-4.3 ± 0.1 c	12.2 ± 0.3 bcd	109.2 ± 0.4 g	-3.9 ± 0.2 c	12.3 ± 0.6 abc	107.8 ± 0.4 f
Week 6, 4 °C	-3.2 ± 0.3 b	12.2 ± 0.3 bcd	104.2 ± 0.6 h	-3.0 ± 0.2 b	11.9 ± 0.4 abc	104.4 ± 0.4 g
Week 8, 4 °C	-2.7 ± 0.1 b	12.8 ± 0.2 ab	101.8 ± 0.4 i	-2.7 ± 0.2 b	12.2 ± 0.6 abc	102.5 ± 0.9 h
Week 12, 4 °C	-1.2 ± 0.2 a	11.3 ± 0.3 d	96.0 ± 1.1 j	-1.4 ± 0.2 a	11.8 ± 0.7 bc	96.7 ± 1.2 i
Week 4, -20 °C	-6.9 ± 0.1 ef	11.8 ± 0.3 cd	120.6 ± 0.4 e	-6.6 ± 0.2 e	11.4 ± 0.5 c	120.1 ± 0.3 d
Week 8, -20 °C	-7.9 ± 0.2 g	12.4 ± 0.4 bc	122.6 ± 0.5 cd	-7.6 ± 0.3 fg	12.1 ± 0.4 abc	121.9 ± 0.3 c
Week 12, -20 °C	-7.6 ± 0.2 fg	12.5 ± 0.3 abc	120.9 ± 0.4 de	-7.0 ± 0.4 ef	12.2 ± 0.5 abc	120.9 ± 0.6 d

Different letters (vertical) indicate significant differences ( $p < 0.05$ )

**Tab. 2:** Color characteristics during processing (90 and 95 °C) and storage (12 weeks at 4 and -20 °C) of pasty celeriac products (n = 6)

Process parameter	90 °C			95 °C		
	<i>L</i> *	<i>C</i> *	<i>h</i> °	<i>L</i> *	<i>C</i> *	<i>h</i> °
Control (unheated)	49.3 ± 0.4 f	24.2 ± 0.7 a	71.8 ± 0.8 e	49.3 ± 0.4 e	24.2 ± 0.7 a	71.8 ± 0.8 e
Steam-blanching	62.3 ± 0.5 ab	16.8 ± 0.7 b	95.3 ± 1.2 d	63.9 ± 0.3 a	14.5 ± 0.7 b	101.4 ± 1.4 d
After processing, week 0	62.8 ± 0.2 a	14.2 ± 0.3 cd	103.0 ± 0.5 bc	62.7 ± 0.2 b	12.2 ± 0.2 cd	106.1 ± 0.5 bc
Week 2, 4 °C	61.7 ± 0.9 bc	12.9 ± 1.0 e	104.7 ± 2.0 ab	61.7 ± 0.5 bc	11.4 ± 0.3 cde	106.0 ± 0.4 bc
Week 4, 4 °C	60.8 ± 0.5 cd	12.4 ± 0.6 e	106.4 ± 1.1 a	61.9 ± 0.3 bc	11.1 ± 0.3 def	107.7 ± 0.5 ab
Week 6, 4 °C	60.8 ± 0.6 cd	12.6 ± 0.7 e	104.6 ± 1.5 ab	60.1 ± 0.3 d	11.1 ± 0.7 def	107.1 ± 2.1 abc
Week 8, 4 °C	58.3 ± 0.4 e	12.6 ± 0.5 e	103.7 ± 1.0 bc	61.0 ± 0.5 cd	10.8 ± 0.3 ef	106.1 ± 1.9 bc
Week 12, 4 °C	60.4 ± 0.5 d	13.2 ± 0.9 de	103.2 ± 0.8 bc	60.4 ± 0.5 d	11.5 ± 0.3 cde	105.8 ± 0.8 bc
Week 4, -20 °C	61.7 ± 0.4 bc	14.1 ± 0.4 cd	102.7 ± 0.8 bc	60.1 ± 1.3 d	10.2 ± 1.4 f	108.8 ± 2.2 a
Week 8, -20 °C	61.8 ± 0.5 b	14.2 ± 0.4 cd	102.7 ± 0.4 bc	61.9 ± 0.8 bc	12.4 ± 0.4 c	105.2 ± 0.4 c
Week 12, -20 °C	62.1 ± 0.2 ab	14.7 ± 0.2 c	102.7 ± 0.6 c	61.6 ± 0.3 bc	12.2 ± 0.3 cd	106.8 ± 0.4 abc

Different letters (vertical) indicate significant differences ( $p < 0.05$ )

parsley and celeriac into pasty products. During cold storage, the green color was retained for 4 weeks, whereas the products may be stored at -20 °C for several months. In contrast, storage of celeriac pastes at 4 and -20 °C is possible for several months without color loss. Furthermore, enzyme activities in celeriac were low and even ceased in parsley. Pasty products are easier to handle, because lumping and dusting are avoided, thus facilitating their easy application in the food processing industry. Their application is proposed for sensitive food sectors such as catering of air carriers, schools, hospitals, and residential homes for the elderly requiring especially high hygiene standards, and for their incorporation into extremely sensitive commodities (e.g. herb butter).

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