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Analytical Methods

Determination of the fruit content of apricot and strawberry jams and spreads and apricot and peach fruit preparations by gravimetric quantification of hemicellulose

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Abstract

An innovative method developed for fruit content determination based on the quantification of hemicellulose was applied to apricot and peach fruit preparations, apricot and strawberry jams and spreads. For this purpose, the hemicellulose fraction was isolated from the alcohol-insoluble residue from peaches, apricots, and strawberries, yielding the amount of the respective fresh fruit per gram hemicellulose. Fruit preparations from peaches with 34.4%, 47.2% and 66.4% fruit content were produced using pectin and carrageenan, xanthan or starch, respectively, as hydrocolloids. Jams from apricots and strawberries were prepared with pectin. Fruit contents of apricot jams were 34.1% and 48.2%, and 36.6% and 46.4% in strawberry jams, respectively. Furthermore, a range of commercial apricot spreads and jams and one strawberry spread as well as apricot and peach fruit preparations were examined. The fruit content was calculated based on the amount of hemicellulose. Calculated fruit contents were in good agreement with the respective product specifications (e.g. 62.6% vs. 66.4%, 35.2% vs. 34.1%, 67.5% vs. 70.0% and 54.0% vs. 53.7%, respectively) with deviations ranging between 0.3% and 4.2%. Maximal deviation was found only in the case of a self-made peach fruit preparation (40.9% vs. 34.4%), where interference of added hydrocolloids and fruit ingredients probably resulted in significant overestimation of the fruit content. Although sample preparation needed to be adapted to different fruit matrices, this novel method proved to be suitable for the determination of fruit contents of fruit preparations, spreads and jams. For the first time, this method was successfully applied to industrially manufactured fruit products without knowledge of fruit specification and the complex recipes of jams, spreads, and fruit preparations, respectively.

Keywords: Alcohol-insoluble residue; Fractionation; Fruit content; Jams; Spreads; Fruit preparations; Hemicellulose; Apricot; Peach; Strawberry

1. Introduction

Definition and labelling of fruit jams, jellies, marmalades, and sweetened chestnut purées intended for human consumption is specified in the European Union Council Directive 2004/84/EC. According to this directive, jams are pectin gelled formulations of sugars, pulp and/or purée of one or more fruit species and water. As a general rule, the amount of fruit used for the manufacture of 1000 g of finished product shall not be less than 350 g. For the production of 'jam extra', the pulp content shall not be less than 450 g per 1000 g of the finished product. For red currant, rowanberry, sea-buckthorn, rosehip, quince, ginger, cashew apple, and passion fruit the recommended fruit quantities in jams and jams 'extra' are reduced to 250, 150, 160, and 60 g, respectively. Furthermore, minimum soluble dry matter of the named products shall amount to 60% as determined by refractometer, except for dietetic products, sugar free and sugar reduced products where sugars have been entirely or partially replaced by intense sweeteners. However, other related fruit based products like spreads, usually having higher fruit contents, less sugar

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and other ingredients like preservatives and hydrocolloids, are not regulated in this directive.

In contrast to jams, fruit preparations are less strictly specified. The definition according to the German Federation of Food Law and Food Science (BLL) implies that fruit preparations are intermediate products for the use in dairy products, bakery products and confectionary, which beside fruits and fruit constituents, usually contain diverse sugars, essences, flavours, colouring foodstuffs, thickening agents, and consumable acids, and are preserved by appropriate methods. In general, their fruit content shall not fall below 35%. Similar to jams, for fruit preparations from selected fruit species, particularly having high acid or aroma content like raspberry or pineapple, fruit content is lowered to 25–30%, depending on the fruit species. Principally, the production of fruit preparations is similar to that of jams, spreads and related products. The fundamental difference lies in the gelation. The formation of irreversible gels is only desired in jams but not in fruit preparations. In the latter case instead of high esterified pectins low esterified pectins and other stabilisers like starches, xanthan, guar gum, and other thickening agents are used. However, in some European countries (Italy, Austria, and Switzerland) only pectins (E 440, E 440a) are permitted.

Since adulteration of fruit based products is an unsolved problem, determination of fruit authenticity and fruit content is a prerequisite for quality control and consumer protection. Therefore, numerous attempts as recently summarised by Fügel, Carle, and Schieber (2005) and Schieber (2008), have been made to develop analytical methods for authentication and fruit content determination in fruit products. Nevertheless, so far all analytical approaches suffer from limitations of their applicability, particularly to technologically processed and/or complex fruit products (Carbonell, Costell, & Durán, 1991; Nehring, Prehn, & Skott, 1978; Wallrauch, 1995).

In the present study, investigations of apricot, peach and strawberry products, based on the approaches described by Kurz, Carle, and Schieber (2008), Schieber, Fügel, Henke, and Carle (2005), Fügel, Förch, Carle, and Schieber (2005) and Fügel, Schieber, and Carle (2006) were carried out. Fruit contents were determined by the fractionation of the alcohol-insoluble residue from fruit products and subsequent gravimetric quantification of hemicellulose. Since, the high molecular hemicellulose showed to be a sufficiently constant parameter which was not affected by processing of the products, its gravimetric determination proved to be a suitable tool for the determination of fruit contents in strawberry and cherry fruit preparations and strawberry yoghurt. Therefore, the novel method was adapted to apricot and peach fruit preparations, apricot and strawberry jams. Furthermore, this method was employed for the first time to determine the fruit contents in commercial spreads, jams and fruit preparation with unknown composition and specification of the fruits. Emphasis was given to apricot, and peach products, since strawberry fruit preparations have been comprehensively examined in a previous investigation (Schieber et al., 2005).

2. Materials and methods

2.1. Materials

2.1.1. Fruits

Blanched and individually quick frozen (IQF) apricots (*Prunus armeniaca* L. cultivar Orange du Provence and a blend of unknown cultivars), lye peeled, blanched and IQF peaches (*Prunus persica* L.; including a mixture of cultivars) and IQF strawberries (*Fragaria x ananassa* Duch cultivar Senga Sengana) were provided by Wild (Eppelheim, Germany). The fruits were harvested in 2004–2006, respectively. Apricots of the cultivar Bergeron of French harvest 2006 were purchased from the local market, cored at 4 °C, blanched at 85 °C for 10 min, and subsequently mashed through a sieve of 1.5 mm mesh size. Calculation of fruit contents in commercial jams of unknown fruit origin was based on fully ripe apricots of the cultivar Bergeron from the local market (Stuttgart, Germany), harvested in France 2005.

Fruits were freeze-dried for 72 h in a Steris Lyovac® GT 4 Lyophiliser (Steris, Hürth, Germany). Subsequently, the dried product was finely ground in a pre-cooled cutter (UM12, Stephan & Söhne, Hameln, Germany) with liquid nitrogen.

2.1.2. Hydrocolloids

For production of fruit preparations modified maize starch NATIONAL 67-0029 from National Starch (Bridgewater, NJ, USA), xanthan "Rhosigel Easy" (Rhodia, Melle, France) and amidated pectin (Pectin Amid AF 010-A) from Herbstreith & Fox (Neuenbürg, Germany) were used. Carrageenan "Gelcarin DG 5264" was purchased from FMC Biopolymer (Brüssel, Belgium). For the production of jams high esterified pectin (Pectin Classic AF 401) provided by Herbstreith & Fox (Neuenbürg, Germany) was applied. Pectins were dispersed with distilled water before admixture to the fruits. Starch and xanthan were blended with sucrose (Südzucker, Mannheim, Germany).

2.1.3. Enzymes

For the enzymatic degradation of the hydrocolloid matrices the following preparations were used: Fructamyl® HT containing a solution of amylolytic enzymes was kindly provided by Erbslöh (Geisenheim, Germany). Hazyme® DCL comprising α-amylase and amyloglucosidase was a gift from DSM Food Specialities (Seclin, France). Galactomannanase granules (0.2 U/mg) from *Aspergillus niger* were obtained from Sigma-Aldrich (Steinheim, Germany).

2.2. Production of fruit products and sample preparation

2.2.1. Fruit preparations

According to compositions adopted from industrial recipes peach fruit preparations in quantities of 1.0 kg were

produced. For this purpose, thawed fruits, water, sugar and the hydrocolloids were blended. The mixture was heated at 96 °C for 6 min in a reaction vessel (EL 3, ESCO-Labor, Riehen, Switzerland). After heating, the fruit preparations containing starch were cooled to the digestion temperature and enzymes were added as indicated in Table 1. Industrial fruit preparations were heated to digest temperature and enzymes were added according to the specification (Table 2). After heating and digestion, the fruit preparations were cooled to room temperature, filled on metal trays and frozen at −20 °C in a deep freezer for 24 h. The frozen samples were lyophilised for 120 h in a Steris Lyovac® GT 4 Lyophiliser (Steris, Hürth, Germany). Subsequently, the dried product was homogenised to a fine powder in a cutter (UM12, Stephan & Söhne, Hameln, Germany) pre-cooled with liquid nitrogen.

2.2.2. Jams

The jams (1.0–2.0 kg) were prepared by cooking of a weighed amount of fruit purée with inverted sugar (72.7 °Brix, Schießmann, Schwäbisch Hall, Germany) and/or sucrose (Südzucker, Mannheim, Germany) and high esterified pectin (Classic AF 401, Herbstreith & Fox, Neuenbürg, Germany) under reduced pressure in a reaction vessel (EL 3, ESCO-Labor, Riehen, Switzerland) at 75 °C until 60% of dry matter was achieved. Subsequently, the jams were cooled to room temperature, acidulated with citric acid to pH 3, filled on metal trays, frozen at −20 °C for 24 h, freeze-dried and powdered with liquid nitrogen as described above. The commercial apricot jams, spreads and strawberry spread were purchased in the central market in Stuttgart; filled on metal trays, frozen at −20 °C, then freeze-dried and powdered with liquid nitrogen.

2.3. Isolation of alcohol-insoluble residue (AIR)

Isolation and gravimetric determination of the AIR output weight for apricots, peaches, strawberries and related products were performed as described by Kurz et al. (2008). However, the input weights for AIR isolation and the number of repetitions of extractions in boiling ethanol were increased for fruit preparations and jams to 50 g and 6, respectively.

The lyophilised fruits and fruit products were homogenised in boiling aqueous ethanol (300 mL, 80%, v/v) using an Ultra-Turrax blender (IKA, Staufen, Germany). After boiling for 1 h, the insoluble solids were collected on a Büchner funnel. Ethanol extraction was repeated 5 or 6 times until a clear extract was obtained. The AIR was stirred overnight in acetone, passed through a G1 glass sinter filter and air-dried at 50 °C for 24 h in a compartment drier (UT 6120, Heraeus, Hanau, Germany). The dried AIR was ball-milled (Retsch, Haan, Germany), sealed in lever lid glass bottles and kept in a desiccator until further analysis.

2.4. Sequential extraction of the AIR

The AIR fractionation of apricots, peaches and related products was performed according to the earlier reported method (Kurz et al., 2008). The procedure of AIR fractionation described by Schieber et al. (2005) was applied for strawberries and strawberry spread and jams.

The AIR (800–1000 mg) of fruits from the genus *Prunus* and related products was suspended in 50 mL of hydrochloric acid (0.05 M) and stirred at 60 °C for 1 h. After centrifugation at 15,000*g* for 20 min, the pellet was washed twice with 50 mL of distilled water. The supernatants were pooled, dialysed exhaustively against distilled water for

Table 1
Formulations and enzymatic matrix degradation of self-made fruit preparation (FP) and jams (J) from peach (P), apricot (A), and strawberry (S), respectively

Sample code	Fruit cultivar	Origin	Recipe (%, w/w)					Enzymatic digestion			
			Fruit	Water	Sucrose	Inverted sugar	Hydrocolloid	Enzyme	Temperature (°C)	Dosage (mL)	Time (h)
Fruit preparations											
P-FP I	Mixture	Greece (2005)	30	49.4	20		Pectin (0.5%) Carrageenan (0.1%)				
P-FP II	Mixture	Greece (2005)	45	34.4	20		Pectin (0.5%) Xanthan (0.1%)				
P-FP III	Mixture	Greece (2005)	60	16.5	20		Pectin (0.5%) Starch (3%)	Fructamyl® HT Hazyme® DCL	50 50	0.75 1.5	1 5
Jams											
A-J I	Mixture	–[a]	35	1.5	43	20	Pectin (0.5%)				
A-J II	Bergeron (2006)	France	45		54.5		Pectin (0.5%)				
S-J I	Senga Sengana	Poland	35	1.5	43	20	Pectin (0.5%)				
S-J II	Senga Sengana	Poland	45	0.5	38	26	Pectin (0.5%)				

[a] Unknown.

Table 2
Composition and enzymatic matrix degradation of commercial fruit preparations (FP), jams (J), and spreads (Sp) from peach/apricot blend (P/A), apricot (A), and strawberry (S), respectively

Sample code	Fruit Cultivar	Origin	Composition according to product specification						Enzymatic digestion			
			Fruit (%)	Water (%)	Sucrose (%)	Inverted sugar (%)	Further ingredients	Hydrocolloid	Enzyme	Temperature (°C)	Dosage[b] (mL)	Time (h)
Fruit preparations												
P/A-FP	–	–	54	–	–	–	–	–	Fructamyl® HT	50	0.75	1
									Hazyme® DCL	50	1.5	5
									Galactomannase	50	6 (mg)	5
A-FP I	–	China	18.7	23.8	35.6	19.1	Aspartame E 951 (0.02%) Acesulfame K E 950 (0.01%), Aroma	Starch 2.4%	Fructamyl® HT	50	0.75	1
									Hazyme® DCL	50	1.5	5
A-FP II	–	China	35	4.8	20	22	Curcuma extract (0.004%), Apricot juice (15.1%), Aroma	Starch 3.0%	Fructamyl® HT	50	0.75	1
									Hazyme® DCL	50	1.5	5
Jams												
A-J III	–	–	45		+	+	Citric acid[a]	Pectin[a]				
A-J IV	–	–	45		+	+	Citric acid[a]	Pectin[a]				
A-J V	–	–	45		+	+	Citric acid[a]	Pectin[a]				
A-J VI	–	–	50		+	+	Citric acid[a]	Pectin[a]				
A-J VII	–	–	50	+	+		Citric acid[a]	Pectin[a]				
A-J VIII	–	–	50		+	+	Citric acid[a]	Pectin[a]				
A-J IX	–	–	55		+		Citric acid[a]	Pectin[a]				
Spreads												
A-Sp I	–	–	55		+		Citric acid[a]	Pectin[a]				
A-Sp II	Orange du Provence	France	55		+		Citric acid[a], Ascorbic acid[a]	Pectin[a], Xanthan[a]				
A-Sp III	–	–	70	+	+		Citric acid[a]					
S-Sp	–	–	55		+	+	Citric acid[a]	Pectin[a]				

–: Not specified.
+: Labelled ingredient without quantitative specification.
[a] Unspecified content.
[b] Per 1.0 kg fruit preparation.

48 h using dialytic membranes (type 36/32, pore size 25–50 Å, Roth, Karlsruhe, Germany). The HCl-soluble pectin (HSP) fraction obtained was subsequently freeze-dried. For further extraction of the residue, alkaline EDTA solution (0.05 M NaOH; 0.5 mM EDTA) was added at 30 °C for 1.5 h. The suspension was centrifuged for 20 min at 15, 000*g* and the pellet washed twice with distilled water. The supernatants were pooled, adjusted to pH 6.5–7.0 with HCl, dialysed for 48 h against distilled water and freeze-dried to obtain the NaOH/EDTA-soluble pectin (OHEP) fraction. The final hemicellulose extraction was carried out using 50 mL of aqueous sodium hydroxide solution (16%, w/w) for 5 h at 30 °C. After centrifugation at 15,000*g* for 20 min, the pellet was rinsed twice with distilled water. The supernatants were pooled and adjusted to pH 6.5–7.0 with HCl, followed by the procedure described for the previous fraction to yield the hemicellulose (HC) fraction. The remaining pellet consisting of insoluble solids such as lignin and cellulose (C fraction) was suspended in 50 mL of distilled water, dialysed and lyophilised.

Different from the extraction described for apricots and peaches, the AIR from strawberry based products was extracted twice with NaOH/EDTA to remove pectins.

2.5. Determination of dry matter

Dry matter was determined after lyophilisation of the samples. The fruits and fruit products were weighed before and after freeze-drying on a metal tray for 96 or 120 h, respectively. Additionally, the dry matter was determined by a moisture analyser (MA 40-000V2, Sartorius, Göttingen, Germany).

3. Results and discussion

3.1. Methodology

Consistent with previous studies on strawberry (Schieber et al., 2005), cherry fruit preparations (Fügel et al., 2006) and strawberry yoghurt (Fügel, Förch et al., 2005), the hemicellulose fraction was used for fruit content determination. For this purpose, the amount of the hemicellulose fraction was correlated with the fresh weight of the fruits and referred as the conversion factor *F*. Additionally, AIR and the dry matter (*DM*) of the analysed fruits are required for calculation according to Eq. (1),

$$F = \frac{I_F \times I_{AIR} \times 100\%}{O_{AIR} \times O_{HC} \times DM_F} \quad (1)$$

where I_F is the initial weight of the respective freeze-dried fruit for AIR isolation, I_{AIR} the weight of the AIR (g) used for fractionation, O_{AIR} the output weight of the isolated AIR (g), O_{HC} the output weight of the HC fraction (g), and DM_F the dry matter of the considered fruit (%). The term $I_F \times 100\%/DM$ represents the fresh weight of the fruits, while, the quotient I_{AIR}/O_{AIR} specifies the aliquot of the fractionated AIR. Isolation of the AIR and its fractionation were performed in triplicate. Since the AIR was pooled, each pair of parameters (I_F, O_{AIR}) from AIR isolation was combined with the respective data obtained from sequential fractionation (I_{AIR}, O_{HC}). The resulting conversion factors, expressed as the average value from nine calculations, are given in Table 3. These values are specifying the amount of fresh fruit corresponding to one gram of the hemicellulose fraction.

Table 3
Dry matter and calculated conversion factor of apricot, peach, and strawberry fruits

Fruits	Cultivar	Dry matter (%)	Conversion factor[a]
Apricot	Bergeron (I)	11.5	523.4 ± 28.2
	Bergeron (II)	13.4	304.1 ± 6.8
	Orange du Provence	15.9	367.6 ± 34.0
	Mixture	10.2	361.0 ± 10.9
Peach	Mixture	9.9	326.9 ± 13.5
Strawberry	Senga Sengana	8.2	331.6 ± 30.1

[a] ±: Standard deviation (abs.%); mean of $n = 9$.

Fruit contents (*C*) of the derived fruit products were calculated from Eq. (2),

$$C(\%) = \frac{F \times O_{HC} \times O_{AIR} \times DM_{FP}}{I_{AIR} \times I_{FP}} \quad (2)$$

where *F* represents the conversion factor, O_{HC} the output weight of the HC fraction (g), O_{AIR} the output weight of the AIR (g), DM_{FP} the dry matter of the fruit product (%), I_{AIR} the initial weight of the AIR (g), and I_{FP} the initial weight of the lyophilised fruit product (g). The product of conversion factor *F* and output weight of the HC fraction O_{HC} represents the fresh weight of the processed fruit. Again, the aliquot of the fractionated AIR is expressed as the quotient O_{AIR}/I_{AIR}, while the parameters DM_{FP} and I_{FP} are required for the calculation of the fresh weight of the fruit product. According to Eq. (1), the fruit content was obtained by combining parameters from gravimetrical determination of AIR and AIR fractionation. Consequently, the fruit contents presented in Tables 4 and 5 are the mean ± standard deviation of 9 values.

3.2. Self-made products

Three types of fruit preparations and two apricot and strawberry jams with fruit contents ranging from 34.1% to 66.4% based on different hydrocolloid systems were produced. The fruit content of the experimental fruit products was calculated with the conversion factor obtained from the fruits processed into the test products. Due to water losses during heating, the initial fruit dosage (Table 1) had to be corrected. Therefore, the real dry matter of the product samples was determined additionally by an electronic moisture analyser to correct the fruit content of the test products. The corrected fruit content was calculated from the initially applied fruit content, the dry matter as per formulation and the dry matter determined in the

Table 4
Dry matter and fruit content of self-made fruit preparations (FP) and jams (J) from peach (P), apricot (A), and strawberry (S), respectively

Sample code	Dry matter (%)	Specified fruit content	Determined fruit content[a]	Deviation from specified fruit content (abs.%)
Fruit preparations				
P-FP I	27.3	34.4	40.9 ± 2.5	+6.5
P-FP II	26.1	47.2	51.3 ± 4.4	+4.1
P-FP III	31.3	66.4	62.6 ± 1.5	−3.8
Jams				
A-J I	65.6	34.1	35.2 ± 1.2	+1.1
A-J II	70.3	48.2	51.4 ± 1.2	+3.2
S-J I	68.6	36.6	40.3 ± 3.5	+3.7
S-J II	71.9	46.4	46.7 ± 6.0	+0.3

[a] ±: Standard deviation (rel.%); mean of $n = 9$.

Table 5
Dry matter and fruit content of commercial fruit preparations (FP), jams (J), and spreads (Sp) from peach/apricot blend (P/A), apricot (A), and strawberry (S), respectively

Sample code	Dry matter (%)	Specified fruit content	Determined fruit content[a]	Deviation from specified fruit content (abs.%)
Fruit preparations				
P/A-FP	41.3	54	53.6 ± 1.5	−0.4
A-FP I	62.4	18	22.6 ± 0.9	+3.9
A-FP II	48.4	35	34.0 ± 5.8	−1.0
Jams				
A-J III	69.1	45	43.7 ± 3.1	−1.3
A-J IV	66.5	45	46.4 ± 2.0	+1.4
A-J V	66.0	45	45.4 ± 5.6	+0.4
A-J VI	68.4	50	48.6 ± 4.2	−1.4
A-J VII	67.0	50	53.9 ± 3.9	+3.9
A-J VIII	67.3	50	53.6 ± 3.5	+3.6
A-J IX	65.5	55	59.2 ± 1.8	+4.2
Spreads				
A-Sp I	56.9	55	58.0 ± 3.8	+3.0
A-Sp II	55.6	55	53.4 ± 4.2	−1.6
A-Sp III	75.2	70	67.5 ± 3.5	−2.5
S-Sp	51.8	55	53.1 ± 5.0	−1.9

[a] ±: Standard deviation (abs.%); mean of $n = 9$.

finished product by moisture analyser. The corrected fruit contents are shown in Table 4.

The fruit contents of the experimental peach fruit preparations are listed in Table 4. Fruit content of sample P-FP II was slightly overestimated (4.1%), while that of sample P-FP III was 3.8% lower than expected. A significant overestimation was only found for sample P-FP I. The 6.5% deviation from the initial fruit content of sample P-FP I might be due to an interference of added hydrocolloids and fruit ingredients. According to the results obtained by Fügel et al. (2006) with cherries, fruit preparations with complex systems of hydrocolloids may cause an overestimation of the fruit content. For removal of the common hydrocolloids different approaches are needed. Whereas starch can be digested enzymatically, pectin, xanthan, and carrageenan must be removed by extraction. As shown in a previous study (Schieber et al., 2005), the α-amylases, amyloglucosidases and galactomannanase, respectively, employed were devoid of hemicellulolytic and cellulolytic side activities, thus avoiding degradation of the essential cell wall fraction. Since commercial pectinases usually display the above mentioned side activities, pectins as well as xanthan and carrageenan were extracted by the first and second step of the fractionation procedure. However, in the present study major overestimation was found with hydrocolloid systems which could efficiently be separated from the hemicellulose fraction in the former investigation (Fügel et al., 2006). Taking into account that two extraction steps were omitted in the fractionation method used in the present investigation compared to the sequential extraction of cherry products, overestimation might be caused by residual carrageenan in the HC fraction, since other hydrocolloid combinations allowed a more precise determination of fruit contents.

Both self-made apricot jams and strawberry jams showed good agreement of expected and determined fruit content (Table 4) with a maximal overestimation of 3.7% in strawberry jam S-J I. Except for sample S-J II, standard deviation did not exceed 10%, thus confirming the good reproducibility of the method earlier reported in the investigations by Schieber et al. (2005) and Fügel et al. (2006).

The results of experimental apricot and peach products showed a slightly inferior accuracy of the calculated fruit contents compared to the former studies on fruit content determination of strawberry fruit preparation. As mentioned in previous investigations (Schieber et al., 2005), minor amounts of pectin are assumed to remain in the residue after alkaline/EDTA extraction, thus interfering with the gravimetric determination of the HC fraction and leading to overestimation. Deviations from the expected fruit contents were found to be in the same range as observed for cherry fruit preparations. However, Fügel et al. (2006) applied a more tedious extraction procedure comprising additional extraction steps. Therefore, to improve practicability, the extraction method was modified as described by Kurz et al. (2008) for fruit content determination in products made from fruits rich in pectin belonging to the genus *Prunus* such as cherries, peaches, and apricots.

3.3. Commercial products

Except for spread sample A-Sp II, the varieties of the fruits used for the production were unknown. Therefore, we have selected appropriate reference fruits from our database for fruit content calculation. To retain textural integrity of the fruits during processing, individually quick-frozen turning ripe fruits are commonly used for industrial production of fruit preparations. Therefore, fruit contents of the industrial fruit preparations were calculated with the conversion factor obtained from a blend of cultivars provided by an industrial manufacturer of fruit preparations. Sample P/A-FP contained peaches and apricots

in proportions of 66.7% to 33.3%. The conversion factor for this product was calculated according to the proportion of peach and apricot in the blend.

Since the flavour of jams and spreads strongly depends on to the ripeness of the processed fruits, fully ripe fruits are commonly chosen for jam production. Therefore, the conversion factor from the aromatic, fully ripe apricot cultivar Bergeron (2005) was taken to calculate the fruit content of apricot jams and spreads. Since overripe fruits are prone to microbial spoilage and textural degradation, thus being unsuitable for industrial jam production, the overripe apricot cultivar Bergeron (2006) was not considered an adequate reference for the calculation of the fruit contents.

The application of the method to commercial jams and spreads was necessary to verify its practicability for fruit content determination by gravimetric hemicellulose quantification. From Table 5 it becomes evident that the fruit contents of the investigated commercial fruit products correlate well with the values specified by the producers. Exceptionally good agreement was found for fruit preparation sample P/A-FP containing a blend of peach and apricot. Only minor deviations of 0.4% between expected and determined fruit content were found. Since hydrocolloid contents were not specified on the label, starch degrading enzymes as well as galactomannanase were employed to digest starch and guar gum, respectively, that the product might contain. Thus, it could be demonstrated that detailed knowledge of the formulation for fruit preparations is not a prerequisite for correct determination of fruit contents. Fruit content of the samples A-FP I and A-FP II was overestimated and slightly underestimated by 3.9% and 1.0%, respectively. Taking into account that the specification of the applied fruit did not disclose the cultivar and the dry matter, the fruit content determined correlated very well with the specified fruit content. Furthermore, it should be noted that industrial fruit preparations are often made with added juice concentrates, e.g. to improve colour. Since the macromolecular matrix of juice and juice concentrate has been mostly degraded, their fruit content cannot be determined by this method, as can be seen from the fruit content determination of sample A-FP II with 15.1% added apricot juice.

Like in the case of industrially manufactured fruit preparations, the results obtained from jams and spreads also showed only slight deviations between specified and determined fruit contents, ranging from an underestimation by 2.5% to overestimation by 4.2%. These deviations observed in jams may be due to the dry matter content of the fruits used, which may significantly differ from that of the reference fruits used for calculation in this study. Another reason for underestimation might be the high sugar content of the products resulting in strongly hygroscopic powders after cryo-milling. Air moisture may easily decrease the quotient O_{AIR}/I_{FP} and consequently the calculated fruit content.

As expected, the fruit content determined in the strawberry spread came close to the specified fruit content. Schieber et al. (2005) already stated that strawberries have varying dry matters, depending on ripeness, thus resulting in deviation of conversion factors. However, compared to the natural heterogeneity of the sugar content in apricots and peaches, differences in the dry matter of strawberries are almost negligible. Thus, fruit content determination in strawberry products was found to be in very good agreement with the specification of the named fruits.

The applicability of the method for fruit content determination via hemicellulose to commercial apricot and peach products as well as strawberry spread was the major aim of the present study. Investigating a broad range of specified fruit contents ranging from 18.7% to 70.0% in fruit preparations, jams and spreads with and without complex hydrocolloid systems showed that the method is applicable even to very complex recipes and over a wide range of contained fruit. Although, the content of hemicellulose proved to be constant in the alcohol-insoluble residue independent of cultivar and processing, the calculated conversion factor is strongly dependent on the dry matter of the reference fruit. Therefore, a comprehensive database of the dry matter content of numerous peach and apricot cultivars is currently being established to further improve the precision of the method. It is obvious that the applied method is tedious and calculation of fruit contents depends on the specific conversion factor of the particular fruit and its ripeness degree, respectively. Nevertheless, the results of the investigated fruit products clearly evidence that fruit content determination based on the applied method is absolutely feasible. Furthermore, the application of this method to commercially manufactured products demonstrated that the innovative method can be used for quality control of industrially semi-finished products and commercially available spreads and jams even without disclosure of recipe. Astonishingly, fruit content determination has been also successfully applied to a fruit preparation with blended fruits. Since all relevant parameters are determined gravimetrically, the procedure can easily be adopted by laboratories of the food industry and the Food Inspection Board. Widespread application and standardisation of this method will finally result in fair competition, reliable quality control, and consumer protection from adulteration of fruit products.

4. Conclusion

In previous studies on strawberry and cherry fruit preparations it has been shown that the hemicellulose fraction can be used for fruit authenticity evaluation and fruit content determination. Its attributes like process stability and only minor variation in its content within the AIR make the hemicellulose fraction a suitable parameter for determination of fruit contents. Admixtures of hemicellulose containing fibres to feign higher fruit contents may be detected by investigating their neutral sugar profiles, as described previously (Fügel, Carle, & Schieber, 2004; Kurz et al., 2008). In the present study, this novel

method was extended to fruit products from apricots and peaches and strawberry spread and jams. Since recipes of commercial fruit based products are quite variable, former approaches on their fruit content determination based on low molecular constituents failed. In this study, it could be shown that the knowledge of the product composition is not mandatory, since all ingredients usually added during manufacture can efficiently be removed by extraction or enzymatic digestion. Although hydrocolloid extraction showed minor limitations using the simplified fractionation method, deviation of calculated fruit content from the real fruit content might be more dependent on the variation of dry matter of the investigated fruits. Due to the observed differences in their dry matter, the application of an average conversion factor would result in less precise fruit content determination. Furthermore, when fruit juice concentrates are added to fruit pulp or purée, only the polysaccharide matrix containing fruit constituents will be determined by this method. Consequently, this method becomes more efficient when the specification of the processed fruits or fruit purées is known or if the fruit is even available for analysis. When exact specification of the applied fruits is missing, the calculation of average conversion factors for different ranges of dry matters will be appropriate, but undoubtedly lowering the accuracy of the determination. Consequently, for semi-finished and finished products the specification of the fruit by the fruit processor is helpful to determine fruit content as exact as possible.

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References

Carbonell, E., Costell, E., & Durán, L. (1991). Rheological indices of fruit content in jams: Influence of formulation on time-dependent flow of sheared strawberry and peach jams. *Journal of Texture Studies, 22*, 457–471.

Fügel, R., Carle, R., & Schieber, A. (2004). A novel approach to quality and authenticity control of fruit products using fractionation and characterisation of cell wall polysaccharides. *Food Chemistry, 87*, 141–150.

Fügel, R., Carle, R., & Schieber, A. (2005). Quality and authenticity control of fruit purées, fruit preparations and jams–a review. *Trends in Food Science and Technology, 16*, 433–441.

Fügel, R., Förch, M., Carle, R., & Schieber, A. (2005). Determination of the fruit content of strawberry yoghurt by gravimetric quantification of hemicellulose. *Journal of Applied Botany and Food Quality, 79*, 157–159.

Fügel, R., Schieber, A., & Carle, R. (2006). Determination of the fruit content of cherry fruit preparations by gravimetric quantification of hemicellulose. *Food Chemistry, 95*, 163–168.

Kurz, C., Carle, R., & Schieber, A. (2008). Characterisation of cell wall polysaccharide profiles of apricots (*Prunus armeniaca* L.), peaches (*Prunus persica* L.), and pumpkins (*Cucurbita* sp.) for the evaluation of fruit product authenticity. *Food Chemistry, 106*, 421–430.

Nehring, P., Prehn, H. J., & Skott, W. P. (1978). Fruchtgehaltsbestimmung in Konfitüren. *Industrielle Obst- und Gemüseverwertung, 63*, 559–566.

Schieber, A. (2008). Introduction to food authentication. In D. W. Sun (Ed.), *Modern techniques in food authentication*. Elsevier.

Schieber, A., Fügel, R., Henke, M., & Carle, R. (2005). Determination of the fruit content of strawberry fruit preparations by gravimetric quantification of hemicellulose. *Food Chemistry, 91*, 365–371.

Wallrauch, S. (1995). Berechnungsformel zur Abschätzung des Fruchtgehaltes in Erdbeerfruchtzubereitungen. *Lebensmittelchemie, 49*, 40–45.