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Texture of Cooked Potatoes (*Solanum tuberosum*). 1. Relationships between Dry Matter Content, Sensory-Perceived Texture, and Near-Infrared Spectroscopy

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Properties of fresh potatoes, including dry matter (DM) content, starch content, and near-infrared (NIR) spectra, were determined and related to the sensory-perceived texture of the steam-cooked samples. To quantify these relationships, three potato cultivars, respectively representing a *firm* cooking potato (cv. Nicola), a *mealy* cooking potato (cv. Irene), and a cultivar (cv. Bintje) with intermediate cooking properties, were classified on the basis of three size categories. For each size category and cultivar a DM distribution was determined on the basis of the underwater weight of the individual potatoes. Each DM distribution was divided into three subcategories based on low, medium, and high DM contents. This categorization was performed for freshly harvested potatoes and for potatoes stored for 3 and 6 months, respectively. In total, this resulted in 27 DM distributions, of which 16 were non-normally distributed, and 81 samples. Linear relationships were established between the DM content, as determined by either underwater weight analysis or oven-drying, and the starch content. On the basis of partial least-squares regression (PLSR), statistical models were developed relating sensory-based texture descriptors with the DM matter content of the samples. It was also shown, by applying PLSR, that the NIR spectra, originating from the potato samples, could be related to the DM content and to the sensory-perceived texture. From the relationships between DM content and sensory-perceived texture, on the one hand, and from the DM content and NIR spectra, on the other, it was concluded that the DM content rather than the cultivar determines the sensory-perceived texture of steam-cooked potatoes. Cultivar-specific elements may also contribute to the perceived texture but are overruled by the DM content. Storage did not affect the mutual relationships between the DM content, the sensory properties, and the NIR spectra.

KEYWORDS: Potato; texture; sensory analysis; dry matter content; near infrared spectroscopy; storage

INTRODUCTION

With reference to the specific demands of the consumer, one of the prime quality attributes of consumption potatoes is texture. It is an essential factor in the consumers' perception of the quality of agrofood products in general and potatoes specifically. The texture of cooked potatoes is, to a great extent, determined by cultivar with superimposed agronomic effects (*1*). The diversity in the texture of cooked potatoes and their derived food products has enabled the potato to meet specific demands of both the food-processing industry and the ware trade. Extensive research to describe cooked potato texture based on either sensory perception (*2*) or rheological measurements (*3*, *4*) has been performed. Using histological, biochemical, and physical approaches attempts, have been undertaken to explain the different texture types and their relationship with mechanical properties (*5*).

With regard to the cooking behavior of potatoes, four main types (A, B, C, and D) are distinguished, ranging from firm, nonmealy (A), to loose, very mealy (D) (*6*). Referring to the different texture types, a correlation exists between the texture of the potato and its constituents, with emphasis on the dry matter (DM) (*2*, *6*) and starch contents, respectively (*7*, *8*). A causal relationship between sensory-perceived texture properties of cooked potatoes and either the dry matter or the starch content is, however, not yet elucidated. In addition, several other factors such as the composition and properties of the cell wall and

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Table 1. Dry Matter Content (Milligrams per Gram of Fresh Weight), Based on Underwater Weight Measurements ($\mathrm{DM}_{\mathrm{UWW}}$) and on Drying ($\mathrm{DM}_{\mathrm{DRY}}$), and Starch Content (Milligrams per Gram of Fresh Weight) of Potato Samples Categorized by Size and Dry Matter Content

			storage period								
			field run			short storage			long storage		
cultivar	size	DM level	$\mathrm{DM}_{\mathrm{UWW}}$	$\mathrm{DM}_{\mathrm{DRY}}$	starch	$\mathrm{DM}_{\mathrm{UWW}}$	$\mathrm{DM}_{\mathrm{DRY}}$	starch	$\mathrm{DM}_{\mathrm{UWW}}$	$\mathrm{DM}_{\mathrm{DRY}}$	starch
Irene	small	low	184 ± 2.9	198	114	182 ± 1.8	194	118	209 ± 1.9	205	134
		medium	239 ± 0.7			233 ± 0.6			243 ± 0.6		
		high	264 ± 1.0	275	189	257 ± 0.6	292	201	265 ± 0.8	302	218
	medium	low	221 ± 1.8	234	149	213 ± 2.6	234	155	228 ± 1.7	254	181
		medium	245 ± 0.5			243 ± 0.6			252 ± 0.5		
		high	263 ± 0.7	275	182	259 ± 0.8	280	200	271 ± 1.0	297	206
	large	low	224 ± 1.0	228	145	225 ± 1.0	246	164	226 ± 1.2	240	169
		medium	242 ± 0.4			244 ± 0.3			249 ± 0.3		
		high	257 ± 0.5	271	176	259 ± 0.5	273	200	262 ± 0.5	289	205
Nicola	small	low	171 ± 1.4	169	108	175 ± 1.1	189	118	176 ± 1.5	179	112
		medium	205 ± 0.7			210 ± 0.6			209 ± 0.7		
		high	235 ± 1.1	244	178	239 ± 0.9	249	171	238 ± 1.0	242	170
	medium	low	189 ± 2.0	198	121	191 ± 3.9	174	105	189 ± 1.9	205	130
		medium	215 ± 0.5			213 ± 0.5			210 ± 0.5		
		high	236 ± 1.5	241	150	232 ± 1.0	246	172	230 ± 1.0	240	166
	large	low	195 ± 0.8	197	120	196 ± 1.1	209	134	192 ± 0.9	199	125
		medium	211 ± 0.3			213 ± 0.3			211 ± 0.3		
		high	227 ± 0.7	231	158	229 ± 0.6	241	162	227 ± 0.7	233	161
Bintje	small	low	188 ± 2.2			192 ± 1.8			203 ± 1.4		
		medium	225 ± 1.1			223 ± 0.8			228 ± 0.7		
		high	249 ± 1.1			247 ± 1.1			254 ± 1.4		
	medium	low	207 ± 1.5			211 ± 1.2			212 ± 1.2		
		medium	235 ± 0.6			229 ± 0.5			233 ± 0.6		
		high	251 ± 1.7			247 ± 1.5			250 ± 0.7		
	large	low	206 ± 1.7			214 ± 1.1			217 ± 1.1		
		medium	230 ± 0.4			231 ± 0.4			236 ± 0.5		
		high	241 ± 0.8			243 ± 0.8			250 ± 0.7		

middle lamella (*9*, *10*) and the ionic composition (*11*) may influence texture.

The sensory-perceived texture of potatoes can be assessed either by laboratory studies using a panel of trained judges or by consumer tests. Substantial research efforts have been performed to replace the subjective type of information, as delivered by sensory analysis, by objective instrumental measurements. The instrumental assessment of the textural characteristics of potatoes has been performed by cutting, compression, puncture, tensile stress, and relaxation and extrusion measurements (*12*, *13*). Parameters of texture profile analysis (TPA) were correlated with the sensory-perceived texture of potatoes (*3*). It was concluded that the TPA data could not effectively substitute for sensory attributes.

The objectives of the current study were (i) to determine the sensory textural properties as well as the near-infrared (NIR) spectra of the potato cultivars Nicola and Irene, representing two extremes with regard to the sensory-perceived texture, and the cultivar Bintje as an intermediate; (ii) to analyze the consequences of categorization of potatoes belonging to the same cultivar, with regard to tuber size, DM content, and storage time, on both the sensory-perceived textural properties and NIR spectra; (iii) to establish correlations and develop predictive models between DM and starch contents, between the NIR spectral properties and perceived textural properties, and between the NIR information and the DM and starch contents, respectively; and (iv) to assess the effects of cultivar-specific properties and storage on these relationships.

MATERIALS AND METHODS

Plant Material and Storage Conditions. Potato tubers of cv. Nicola, Irene, and Bintje were grown under standard agricultural conditions on clay soil in The Netherlands in 1995. These cultivars represent distinct types of cooking behavior (*2*). Lots of a restricted population of identical growth history were stored after harvest at 6 °C using a sprout inhibitor (chloropham). One lot of potatoes was investigated immediately after harvesting [field-run (FR) potatoes], whereas the remainder was stored for either 3 months [first storage (FS) experiment] or 6 months [second storage (SS) experiment]. Before each moment of analysis the lots were divided into three size categories: 30−45 mm (small), 45−55 mm (medium), and 55−65 mm (large). From each size category a dry matter distribution was made (see below).

Dry Matter Distribution (Underwater Weight Analysis). A DM distribution was determined for the three size categories of each cultivar, at each analysis time. This in total resulted in 27 distributions. The distributions were obtained by measuring the underwater weight (UWW) of 400 individual tubers. The dry matter content ($\mathrm{DM}_{\mathrm{UWW}}$) of the individual potatoes was calculated from the difference between the underwater weight (UWW) and the normal weight (NW), using eq 1, according to Von Scheele (*14*).

$$\%\ \mathrm{DM} = 2 + \frac{246 \times \mathrm{UWW}}{\mathrm{NW}} \tag{1}$$

From each distribution 100 potatoes (25%) with the lowest $\mathrm{DM}_{\mathrm{UWW}}$ and 100 potatoes with the highest $\mathrm{DM}_{\mathrm{UWW}}$ were sampled. These samples respectively represented the subcategories with the low and high DM contents. The remainder of the batch represented the medium DM subcategory (50% of a size category). The $\mathrm{DM}_{\mathrm{UWW}}$ value of each subcategory was calculated as the average value. This sampling scheme was applied for all three cultivars and the three tuber sizes. For the three storage periods studied this resulted in 81 different samples (see **Table 1**).

Samples Analyzed. All 81 different samples were subjected to sensory analysis. NIR spectra were recorded from 72 samples (see below). The DM content, on the basis of oven-drying ($\mathrm{DM}_{\mathrm{DRY}}$), and starch content were determined for part of these samples. The samples selected for the determination of the DM ($\mathrm{DM}_{\mathrm{DRY}}$) and starch contents were from cv. Nicola and Irene. Samples were withdrawn from the low and high DM ends of the DM (DM_{UWW}) distribution (see above) for the small, medium, and large potatoes. This was performed for the field run as well as the stored potatoes. This resulted in 36 different samples being analyzed (see **Table 1**).

Sensory Texture Analysis. The panel, consisting of 16 panelists with ample experience in sensory evaluation on other vegetables and fruits, was trained as described previously (*2*, *15*). The panel members were trained, using the 12 descriptors generated previously (*2*), on a range of potato cultivars, followed by intensity scaling during a period of 2 months. The 12 descriptors used consisted of eight mouthfeel (M) descriptors (firm-M, crumbly-M, moist-M, sticky-M, grainy-M, waxy-M, mealy-M, and mashable-M) and four appearance (A) descriptors (waxy-A, crumbly-A, sticky-A, and breakable-A). To maintain the panel's skills, each 4−6 weeks a session was held.

Potato samples were, in accordance with Van Marle (*2*), hand-peeled and steam-cooked (100 °C; 10^5 Pa) for 30 ± 5 min, depending on size. After cooking, the potatoes were halved along the longitudinal (stem to bud) axis. Each panelist evaluated one half.

Acquisition of NIR Spectra. From the 81 subcategories 20 potatoes were randomly selected, peeled, and cut into four equal parts. Potatoes were first halved along the longitudinal (stem to bud) axis. Each half was bisected into equal parts again along the longitudinal axis perpendicular to the first cut. One-fourth of each potato was taken, cut into smaller pieces, and homogenized (Retsch ultracentrifuge mill) at maximum speed for ∼60 s. The homogenates were used to record the NIR spectra and to determine the dry matter (DM_{DRY}) and starch contents (see below). The remainder of the sample was used for chemical analysis of the cell wall material (*15*). The homogenized samples were packed into standard black cups. Spectra were recorded in the reflectance mode using an InfraAlyzer 500 instrument (Bran and Luebbe), using Sesame data acquisition software. Measurements were made in a wavelength range between 1100 and 2500 nm at 4-nm intervals at 20 ± 1 °C. The detected diffuse reflectances (R) were transformed into apparent absorbencies (log 1/R). The mean spectrum of two repacks for each sample was used for calibration. From the NIR spectra the medium DM level of the field run potatoes of three cultivars were lost, resulting in 72 NIR spectra.

Dry Matter Determination (Oven-Drying). The DM content (DM_{DRY}) of the samples was determined by drying a known weight of homogenized sample (see NIR spectra) overnight at 70 °C, followed by 3 h at 105 °C. After cooling to room temperature, the samples were weighed again. The DM content was calculated from the weight difference. Duplicate samples were taken, starting from the homogenized sample. The value of the DM content obtained by drying will be referred to as DM_{DRY} to distinguish it from the value of the DM content obtained by underwater weight analysis (DM_{UWW}).

Starch Content. To solubilize starch, 5 mL of HCl (8 M) and 20 mL of DMSO were added to 250 mg of a homogenized sample (see NIR spectra). The mixture was placed in a water bath at 60 °C. After an incubation period of 60 min under continuous shaking, 5 mL of NaOH (8 M) and citrate buffer (Titrisol/pH 4, Merck 9884) were added to a final volume of 100 mL. After filtration, 0.1 mL of filtrate was used to quantify the starch content in the sample using test combination catalog no. 207748 from Boehringer, Mannheim. Duplicate samples were taken starting from the homogenized sample.

Data Analysis. Principal component analysis (PCA), partial least-squares regression (PLSR), and soft independent modeling of class analogy (SIMCA) were performed using the statistical program Unscrambler, version 6.1 (Camo A/S). PCA focuses on data reduction, enhancing their ease of interpretation (*16*). Data reduction is obtained by transforming the originally measured, numerical information into new variables, the principal components (PCs), which are linear combinations of the latter. Most of the information is put into the first PC, followed by the second, third, etc. A reduction of the dimension of the data structure of up to 95% of all information is generally contained in the first two to three PCs. PLSR allows the simultaneous use of strongly interrelated X-variables by focusing the systematic covariances in the X-block into a few latent variables (*17*). The predictive ability of the model is described by the root mean squares error of prediction (RMSEP) (*18*). Both the PCA and PLS models were validated by full cross-validation, guarding against overfitting. Full cross-validation is a method in which as many models are made as number of samples analyzed. However, each time one of the samples is left out and is used only for testing. The squared difference between the predicted and real Y-values for each omitted sample is summed and averaged, giving the validation Y-variance. SIMCA (*19*) was used to distinguish between different classes of samples and to reliably assign new samples to existing classes (*19*).

All other statistical analyses were performed using the program S-Plus from Insightful Corp. These included the Kolmogorov−Smirnov test (*21*) to analyze if the individual potatoes within the 27 size categories were normally distributed. The nonparametric analysis of variance by ranks, according to Kruskal-Wallis (*22*) was used to test the significance of the effect of storage on the distribution of a sub-category. Weighted least-squares regression, as described in Draper and Smith (*23*), was applied to establish linear relationships and their confidence intervals between DM_{DRY} and DM_{UWW}, as well as between the starch content and DM_{UWW}.

RESULTS AND DISCUSSION

Dry Matter Distributions. In total 27 DM distributions were made for tubers of cv. Nicola, Irene, and Bintje using three size categories and three storage times using underwater weight analysis (*14*). From each distribution the low, middle, and high ranges were collected representing 25, 50, and 25% of the total amount of potatoes within a distribution, respectively. This resulted in 81 different samples. The average DM contents based upon underwater weight analysis (DM_{UWW}) of these 81 samples are presented in **Table 1**. As examples the probability densities of the DM content, based on underwater weight analysis, for small, medium, and large field run potatoes of, respectively, cv. Nicola, Bintje, and Irene are presented in **Figure 1**. From this figure two general observations can be made. The first observation is that, as expected, the peak values for the DM_{UWW} at each size category increase in the range Nicola, Bintje, Irene. The second observation is that at increasing size category the distribution becomes narrower. This is most likely caused by the fact that the category of small potatoes consists of both immature and mature potatoes (**Figure 1A**) and the category of large potatoes (**Figure 1C**) mainly consists of mature potatoes. To analyze if the data of the 27 DM distributions were normally distributed, the Kolmogorov−Smirnov test (*21*) was used. In total 16 of the 27 distributions were not normally distributed ($p \leq 0.05$). Not normally distributed were Bintje small (second storage), Bintje large (field run and first storage), Nicola small (first storage), Nicola medium (field run and first storage), Nicola large (first storage), and all DM distributions of cv. Irene. For this reason all further analyses concerning the distributions were performed on the basis of nonparametric test methods. The Kruskal−Wallis test for the nonparametric analysis of variance by ranks (*22*) was used to test if storage affects the distributions of a sample. At $p \leq 0.05$ it was observed that storage had an effect on the average DM_{UWW} value of a given distribution.

Dry Matter and Starch Contents. The DM content, obtained by means of oven-drying (DM_{DRY}), and the starch content of the samples with high and low DM (DM_{UWW}) contents (n = 36) of cv. Nicola and Irene were also determined (see **Table 1**). The average coefficient of variation, the ratio of the standard error over the average, of these 36 samples was 0.66% for DM_{DRY} and 2.6% for starch, respectively. Weighted least-squares regression, as described in Draper and Smith (*23*), was used because of the difference in variance between potatoes with a low compared with a high DM_{UWW} value. This variance decreases at increasing DM_{UWW} (see **Figure 2**). The difference in variance is also expressed in the width of the probability

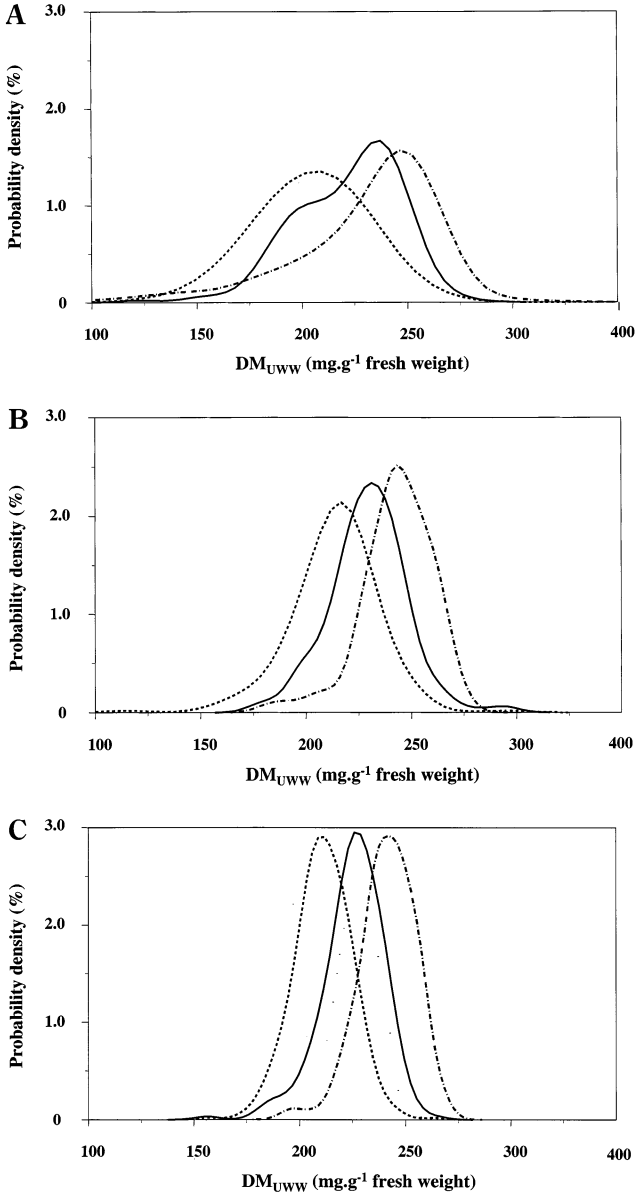

Figure 1. Probability density distribution (percent) of the dry matter content determined by underwater weight measurements (DM_{UWW}) of small (A), medium (B), and large (C) field run potatoes: Nicola (•••); Bintje (—); Irene (– - –).

densities (see **Figure 1**). At increasing DM_{UWW} the width at half the peak height of a probability density tends to decrease.

Samples to be analyzed for their DM and starch contents were withdrawn from either the low, middle, or high end of a distribution. Because potato samples were withdrawn from (part of) a distribution, it is reasonable to assume that this selection procedure causes the primary source of the variance. For this reason all variance in the weighted least-squares regression is ascribed to the DM_{UWW}. This analysis resulted in the following relationship between, respectively, DM_{DRY} and DM_{UWW} (see **Figure 3A**)

$$DM_{UWW} = 0.775 \times DM_{DRY} + 42.4 \quad (R^2 = 0.95, \text{RMSEP} = 7.83) \quad (2)$$

between the starch content and DM_{UWW} (see **Figure 3B**)

$$DM_{UWW} = 0.868 \times \text{starch} + 88.9 \quad (R^2 = 0.87, \text{RMSEP} = 11.0) \quad (3)$$

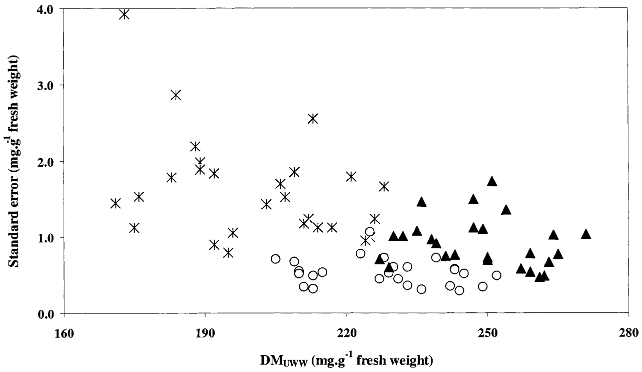

Figure 2. Standard error of the average dry matter content (DM_{UWW}) of the different samples analyzed, as related to the dry matter content determined by underwater weight measurements: low dry matter content (+); medium dry matter content (○); high dry matter content (▲).

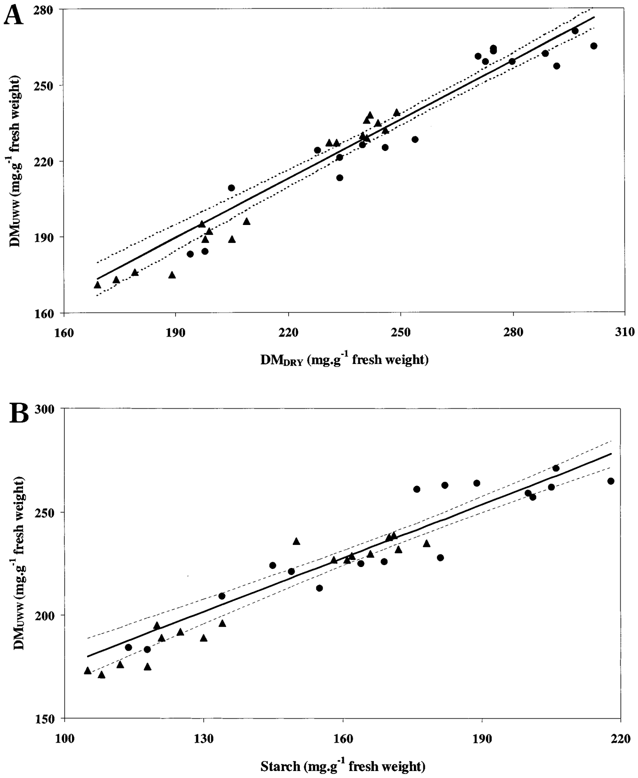

Figure 3. Linear relationship between dry matter content as determined by underwater weight analysis (DM_{UWW}) and dry matter content as determined by oven-drying (DM_{DRY}) (A) and starch content (B): weighted least-squares regression (—); 95% confidence interval (•••); cv. Irene (▲); cv. Nicola (●).

and between the starch content and DM_{DRY}

$$DM_{DRY} = 1.12 \times \text{starch} + 59.2 \quad (R^2 = 0.96, \text{RMSEP} = 7.24) \quad (4)$$

It has to be realized that eq 4 is based on normal linear regression, because all variance was ascribed to DM_{UWW}. The consequence of eq 2 is that, for this limited set of cultivars, eq 1 does not accurately describe the DM content, DM_{DRY}, determined by oven-drying.

Relationship between Dry Matter Content and Sensory-Perceived Textural Properties of Steam-Cooked Potatoes. Sensory research was performed on the three potato cultivars to quantify the effects of cultivar, tuber size, DM content, both

Table 2. Results of Partial Least-Squares Regression between Dry Matter Content, both DM_{UWW} and DM_{DRY}, Starch Content, and Sensory Perceived Texture Descriptors

statistical information	variables				
X-variables	texture descriptors[a]	texture descriptors[b]			
Y-variable	DM_{UWW}	DM_{UWW}	DM_{UWW}	DM_{DRY}	starch
aim of analysis	calibration	calibration	validation	calibration	calibration
calibration					
R_{calcd}	0.92	0.93	0.94	0.94	0.91
$RMSEP_{calcd}$	9.60	9.12	8.87	11.7	12.4
cross-validation					
R_{val}	0.91	0.92	nr	0.92	0.89
$RMSEP_{val}$	10.2	9.82	nr	12.9	13.8
no. of PCs	2	3	2	2	2
calibration set	$n = 81$	$n = 81$	$n = 60$	$n = 36$	$n = 36$
test set	nr[c]	nr	$n = 21$	nr	nr

[a] Descriptors used: firm-M, crumbly-M, moist-M, sticky-M, grainy-M, waxy-M, mealy-M, mashable-M. [b] Descriptors used: crumbly-M, moist-M, sticky-M, grainy-M, mashable-M. [c] nr, not relevant.

DM_{UWW} and DM_{DRY}, and storage time on the perceived textural properties. Cv. Irene (mealy) and cv. Nicola (nonmealy) represent extremes in textural properties. Cv. Bintje exhibits intermediate textural properties (*2*).

In the first instance the effect of storage on the perceived texture was analyzed. PCA models were made of the sensory information of each storage period. These models were made for all of the descriptors (mouthfeel and appearance) and for the mouthfeel descriptors alone. Each PCA model of a given storage period can be considered as a distinguishable class. No differences could be observed between these classes using SIMCA (data not shown). This suggests that, in agreement with Van Marle (*2*), storage did not significantly affect the sensory-perceived behavior of the potato samples analyzed. For this reason the analysis of the sensory data was performed for the three storage periods together.

PCA of all 12 sensory descriptors (mouthfeel and appearance) and all samples ($n = 81$) resulted in a loadings plot for these descriptors that is very similar to the one described by Van Marle (*2*). The two PCs explained 95 and 1% of the variance, respectively (data not shown). Because the observed texture mainly relates to mouthfeel, the remainder of this section will focus on the mouthfeel descriptors. The mouthfeel descriptors firmness-M, waxy-M, sticky-M, and moist-M, which have negative loadings on the first PC, are positively correlated with each other ($0.70 \leq R^2 \leq 0.91$). The mouthfeel descriptors mealy-M, crumbly-M, mashable-M, and grainy-M, which have positive loadings on the first PC, are also positively correlated with each other ($0.89 \leq R^2 \leq 0.97$). The descriptors of the first group are negatively correlated with the ones of the second group ($-0.80 \leq R^2 \leq -0.90$). Because most of these descriptors are correlated with one another, this suggests that they do not vary independently, making them suitable for PLSR analysis (*18*). A PLSR analysis of DM_{UWW} values ($n = 81$) with the eight mouthfeel descriptors showed that these descriptors can predict the measured DM_{UWW} values (see **Table 2**). A further analysis showed that the descriptors firm-M, waxy-M, and mealy-M did not significantly contribute to this PLSR model because the values of their regression coefficients were negligible. This suggests that information present in these three descriptors is either redundant or also contained in the five remaining mouthfeel descriptors. The result of the PLSR analysis of DM_{UWW} with the five remaining mouthfeel descriptors is also presented in **Table 2**. To verify the reliability of this result, a PLSR model was developed using these five remaining mouthfeel descriptors and 60 randomly selected samples. This model was validated on the remainder of the samples ($n = 21$), which served as test set. The result of this validation shows that the PLSR model based on the 60 samples could predict the sensory-perceived texture of the potatoes of the test set on the bases of their DM_{UWW} values (see **Table 2**). On the basis of the information supplied, it can be concluded that a batch of potatoes with a low DM content is, irrespective of the cultivar, always moist-M and sticky-M and never crumbly-M and grainy-M. In addition, a batch of potatoes with a high DM content is, irrespective of the cultivar, always crumbly-M and grainy-M and never moist-M and sticky-M. This implies that potato samples from cv. Irene, with a DM content in the range of the DM content of potatoes of cv. Nicola, will have the sensory-perceived characteristics of the latter cultivar. To verify this hypothesis, a PLSR model of the DM_{UWW} with the five mouthfeel descriptors, presented in **Table 2**, was made for the cv. Bintje and Nicola together ($n = 54$). This model was used to predict the DM_{UWW} values of the 27 samples of cv. Irene. The results of this prediction, characterized by $R^2 = 0.87$ and RMSEP=12.7, are shown in **Figure 4**.

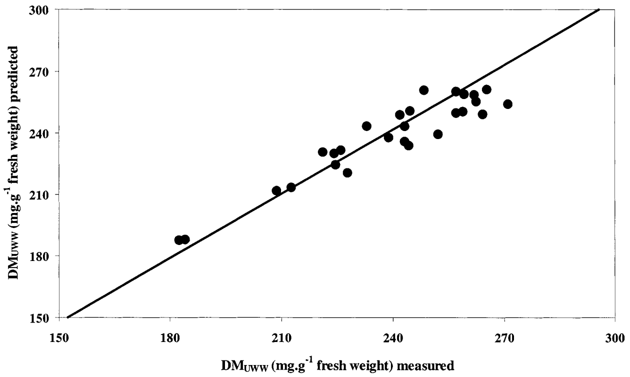

Figure 4. Prediction of dry matter content (DM_{UWW}) of potatoes of cv. Irene, based on a partial least-squares regression model relating five mouthfeel descriptors of cv. Bintje and Nicola with their DM_{UWW} values.

On the basis of the information supplied, it seems realistic to conclude that the contribution of the DM content to the sensory-perceived texture strongly overrules the contribution of cultivar-specific texture-related sensory properties. As a consequence the DM content and several texture-related descriptors

Table 3. Results of Partial Least-Squares Regression between Dry Matter Content, both DM_{UWW} and DM_{DRY}, Starch Content, and Near-Infrared Spectra

statistical information	variables			
X-variables	NIR spectra			
Y-variable	DM_{UWW}	DM_{UWW}	DM_{DRY}	starch
aim of analysis	calibration	validation	calibration	calibration
calibration				
R_{calcd}	0.96	0.94	0.96	0.99
$RMSEP_{calcd}$	7.00	8.46	9.37	5.07
cross-validation				
R_{val}	0.93	nr	0.93	0.95
$RMSEP_{val}$	9.11	nr	12.9	9.88
no. of PCs	7	7	5	7
calibration set	$n = 72$	$n = 53$	$n = 36$	$n = 36$
test set	nr[a]	$n = 19$	nr	nr

[a] nr, not relevant.

Table 4. Results of Partial Least-Squares Regression To Assess the Effect of Potato Cultivar on the Relationship between the Dry Matter Content (DM_{UWW}) and the Near-Infrared Spectra

statistical information	variables		
X-variables	NIR spectra		
Y-variable	DM_{UWW}	DM_{UWW}	DM_{UWW}
aim of analysis	prediction	prediction	prediction
calibration set	Bintje + Nicola ($n = 48$)	Bintje + Irene ($n = 48$)	Irene + Nicola ($n = 48$)
calibration			
R_{calcd}	0.98	0.96	0.96
$RMSEP_{calcd}$	5.11	6.51	7.65
cross-validation			
R_{val}	0.92	0.92	0.93
$RMSEP_{val}$	9.23	9.22	10.4
test set	Irene ($n = 24$)	Nicola ($n = 24$)	Bintje ($n = 24$)
calibration			
R_{calcd}	0.93	0.88	0.94
$RMSEP_{calcd}$	12.7	10.6	6.84
no. of PCs	7	7	6

are strongly related. It should be noted that in the current study the potatoes were submitted to one standardized processing step, steam cooking. No preprocessing was applied. Previously, it has been shown that preprocessing (low-temperature blanching) affects the mechanical properties of fruits and vegetables in general (*20*) and, more specifically, of the three potato cultivars studied (*21*). The results of preprocessing on the sensory-perceived texture and the cell wall properties will be reported separately (*22*).

Relationship between NIR Spectra, Dry Matter and Starch Contents, and Sensory-Perceived Texture. PLSR analysis was used to quantify the relationship between the NIR spectra and the DM content, both DM_{UWW} and DM_{DRY}, and the starch content, respectively. The results (**Table 3**) show that NIR can predict the DM content, both DM_{UWW} and DM_{DRY}, as well as the amount of starch. The capability of NIR to predict the DM content of potatoes was shown before (*23*). In the current study the spectra of homogenates of 20 potatoes, representing one subcategory, were analyzed. Scanlon (*23*) performed the measurements on defined sections of individual potatoes. In view of the positive correlation between starch and DM contents (see eqs 2−4) it was to be expected that the starch content could also be predicted by NIR (see **Table 3**).

The relationship between the sensory-perceived texture descriptors and NIR spectral data has been shown previously (*24*). From the data presented in this study the following correlations were established between the NIR spectra and the descriptors: moist-M ($R^2 = 0.85$), mealy-M ($R^2 = 0.79$), crumbly-M ($R^2 = 0.79$), waxy-M ($R^2 = 0.77$), grainy-M ($R^2 = 0.73$), mashable-M ($R^2 = 0.70$), and firm-M ($R^2 = 0.68$).

Fresh agrofood products, with emphasis on vegetables, contain substantial amounts of water. Their NIR spectra relate to this water, its amount, distribution, and bound state. In addition, adsorptions originating from major components, for example, starch, or cell wall constituents (*24*) also contribute to these spectra. In the case of potatoes it can furthermore be anticipated that the NIR spectra contain elements related either to the DM content or to cultivar-specific properties. Concerning their sensory-perceived texture the DM content strongly predominates the cultivar-specific elements. To test if in the NIR spectra the DM-related elements prevail over the cultivar-specific elements, a SIMCA analysis was performed. The NIR spectra of the three cultivars were used as different classes. On the basis of this classification no differences among these three cultivars could be observed (data not shown). To quantify this approach, three PLSR models were made in which the NIR information was correlated with the DM_{UWW}. These models were made for the different samples of cv. Nicola + Irene ($n = 48$), cv. Nicola + Bintje ($n = 48$), and cv. Bintje + Irene ($n = 48$). The reliability of these three models was tested concerning their predictive ability of the DM_{UWW} values of the potato samples of cv. Bintje, Irene, and Nicola, respectively. The results show that the predictive power, expressed as R^2_{calcd}, of these models ranged between 0.78 and 0.89 (see **Table 4**). This supports the idea that for steam-cooked potatoes the contribution of the dry matter to the sensory-perceived texture content strongly overrules the contribution of cultivar-specific texture-related sensory properties.

Conclusions. The DM content rather than the potato cultivar determines the sensory-perceived texture of steam-cooked potatoes.

The DM content correlates with both the sensory-perceived texture and the NIR spectra.

Storage did not affect the sensory-perceived texture nor its relationship between texture and NIR spectra, but it did affect the SM distribution of the potato cultivars studied.

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