THESIS OF DISSERTATION

Complex evaluation of quick-frozen sweet corn products

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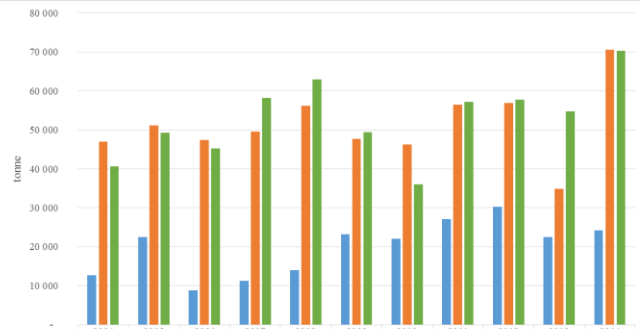
1. INTRODUCTION

The climatic and agro-ecologic conditions of Hungary provide good conditions to the cultivation of sweet corn (*Zea mays var. saccharata* L.) (FRUITVEB, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013). The cultivation and processing of the quick-frozen sweet corn are of national economical importance. Thanks to the increasing purchase prices in the past 20 years, the size of the production area had multiplied (1992=9000ha; 2014=37000ha) (SYNGENTA, 2014; KSH, 2015; FÓRIÁN, 2014). Concerning the exported quantity of quick-frozen sweet corn, Hungary belonged to the biggest exporters in the past decade and became a market leader in the past few years.

In general terms, the international and national sweet corn improvement has executed the species selection under consideration of the points of cultivation and the processing industry itself. At the same time, the members of the sweet corn business – producers, processors, traders, customers – have set sharply different demands toward the individual species. The internal properties of the quick frozen sweet corn species and the related experiments are incomplete; therefore, the increasing potential of the nutrition-physiological value of the sweet corns are unexploited. For the further spreading of the quick-frozen sweet corn in the market, a series of scientifically well founded and statistically proven complex measurements is required.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
France	12 711	22 498	8 732	11 247	13 951	23 180	22 040	27 170	30 305	22 484	24 288
USA	47 039	51 181	47 434	49 640	56 198	47 742	46 278	56 523	56 945	34 896	70 610
Hungary	40 675	49 336	45 282	58 289	63 017	49 500	36 000	57 150	57 780	54 720	70 300

France USA Hungary

Figure 1. Export volume data for quick-frozen sweet corns (AETMD, USDA 2015)

2. OBJECTIVES

The goal of my work is to accomplish the research needed to the determination of the consumer quality establishing the market potential of the quick-frozen sweet corn. The main goals of my thesis are the complex analysis of the quick-frozen sweet corn species from consumers' point of view, the analysis of the internal parameters of the species and the determinations of the similarities and differences caused by the sensory parameters. The objects of the research within the main goals are shown as follows:

1. **Objects concerning the sensory parameters of the quick-frozen sweet corn species tested:**
   - determining the full sensory profiles,
   - creating external and internal preference maps,
   - prediction of the consumers' satisfaction using mathematical models,
   - product optimisation for the consumer segments, determining the ideal product combinations, comparing the consumer segments.

2. **Instrumental and analytical objects concerning the nutrition-physiological potential of the tested quick-frozen sweet corn species:**
   - determining and characterising the colour profiles,
   - determining and characterising the texture profiles,
   - determining the carbohydrate content (glucose, fructose, sucrose),
   - determining the dry matter content,
   - determining the total carotenoid content,
   - characterising the antioxidant capacity,
   - determining the most important micotoxin levels (zearalenon, fumonisin).

The practical goal and benefits of the thesis are that the results help to increase the internationally high volume of export and sales of the Hungarian quick-frozen sweet corn as well as the national consumption at the same time.

3. MATERIALS AND METHODS

The objects of the research were the samples of the quick-frozen sweet corn (*Table 1.*).

Table 1. List of the sweet corn varieties and their maintainers

Serial no.	Name (maintainer)	Serial no.	Name (maintainer)	Serial no.	Name (maintainer)
1	*'Basin R'* (SVS Holland BV)	15	*'GSS 5649'* (Syngenta Seeds BV)	29	*'Puma'* (Crookham Co.)
2	*'Boston'* (Syngenta Seeds BV)	16	*'GSS 8529'* (Syngenta Seeds BV)	30	*'Rebecca'* (Pop Vriend BV)
3	*'Box R'* (Topcorn Kft.)	17	*'Jubilee'* (Syngenta Seeds BV)	31	*'Rocket'* (Harris Moran Seeds Co)
4	*'Dessert 82'* (Topcorn Kft.)	18	*'Jumbo'* (Crookham Co.)	32	*'Royalty'* (Pop Vriend BV)
5	*'Dessert R68'* (Topcorn Kft.)	19	*'Jurassic'* (Syngenta Seeds BV)	33	*'Rustler'* (Vilmorin-NL)
6	*'Dessert R78'* (Topcorn Kft.)	20	*'Kinze'* (HM Clause SA)	34	*'Sheba'* (Asgrow Seeds Co)
7	*'Dynamo'* (Harris Moran Seeds Co.)	21	*'Kuatour'* (Harris Moran Seeds Co.)	35	*'Spirit'* (Syngenta Seeds BV)
8	*'Enterprise'* (Snowy River Seeds Ply Ltd.)	22	*'Legend'* (HM Clause SA)	36	*'Shinerock'* (Syngenta Seeds BV)
9	*'Galaxy'* (HM Clause SA)	23	*'Madonna'* (SVS Holland BV)	37	*'Starshine'* (Syngenta Seeds BV)
10	*'Garrison'* (Syngenta Seeds BV)	24	*'Mercur'* (Royal Sluis BV)	38	*'Sweetstar'* (Syngenta Seeds BV)
11	*'GH 2042'* (Syngenta Seeds BV)	25	*'Merit'* (Royal Sluis BV)	39	*'Tasty Sweet'* (IFS Inc.)
12	*'SC 1036'* (Seminis)	26	*'Noa'* (Pop Vriend BV)	40	*'TOP 825'* (Topcorn Kft.)
13	*'GH 6225'* (Syngenta Seeds BV)	27	*'Overland'* (Syngenta Seeds BV)	41	*'Turbo'* (Harris Moran Seeds Co.)
14	*'GSS 1477'* (Syngenta Seeds BV)	28	*'Prelude'* (Snowy River Seeds Ply Ltd.)		

The primary research relies upon two main bases (**Figure 2.**).

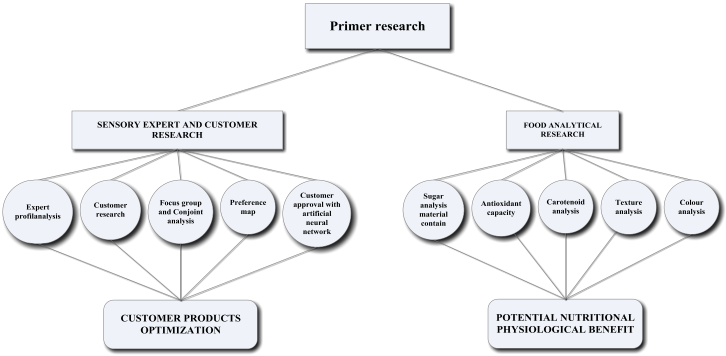


Figure 2. Structure and units of the research

1. **Sensory evaluation methods used in the study:**
   - determining the sensory profiles (ISO 11035:1994, ProfiSens special software),
   - creating preference maps (PCA on expert data, Agglomerative Hierarchal Clustering on consumer data (Euclidean distance, Ward method, XLSTAT software),
   - prediction of consumer acceptance by mathematical models, testing and optimisation of artificial neural networks (MLFN/MLPN Best Net Search, Palisade Neural Tools ver. 5.5 software),
   - product optimization for the consumer segments, determining the ideal product combination, comparing the consumer (consumer focus groups, value-based conjoint by using orthogonal blocks, SPSS 22.0 software).

2. **Instrumental and analytical objects concerning the nutrition-physiological potential of the tested quick-frozen sweet corn species:**
   - determining and characterizing the colour profiles (CIELab L*a*b* colour coordinates, Minolta Chromameter CR-400 colour meter),
   - determining and characterising the texture profiles (Brookfield LFRA Texture Analyser, TexturePro Lite v1.1 Build 4 software),
   - determining the carbohydrate content (glucose, fructose, sucrose) (HPLC, High Performance Liquid Chromatography),
   - determining the dry matter content (in drying box at 105°C until reaching mass constancy),
   - determining the total carotenoid content, (spectrophotometer, Lichtenthaler and Buschmann (2001) method),
   - characterizing the antioxidant capacity (DPPH, FRAP, TPC, ABTS),
   - determining the most important micotoxin levels (zearalenon, fumonisin, chromatographic immunological test of the lateral fluid).

4. RESULTS

4.1. Results relating to the sensory methods

4.1.1 Results of the expert panel, sensory profile of the species

The most important results of the profile analysis are the profile diagrams characterising the species in full. The profile diagram of the reference sample *('Royalty')* is shown as an example in **Figure 3.**

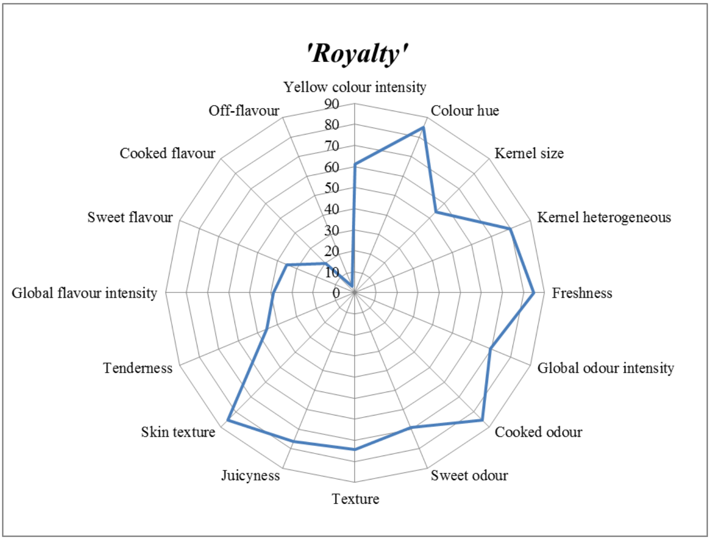


Figure 3. Full sensory profile diagram of the *'Royalty'* sweet corn

All possible sensory profiles of the 41 species of quick-frozen sweet corn were created. One-way analysis of variance (ANOVA) and the calculation of the Tukey HSD pair-wise comparisons were carried out to determine the homogenous and heterogeneous groups. The sweet corn species having similar sensory profiles were clustered by Agglomerative hierarchal clustering, Euclidean distance, Ward method (*Table 2.*).

Table 2. Result of the cluster analysis and the species nearest to the cluster centre by the SRD method (highlighted by gray)

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**
Number of species within the cluster	6	11	5	8	2	9
Variance within the class	6450.31	3534.24	6839.94	4999.81	10827.79	1519.64
Minimal distance from the centre	46.63	39.12	63.12	37.47	71.72	22.60
Average distance from the centre	71.55	55.81	73.40	64.03	84.41	35.71
Maximmum distance from the centre	98.42	69.90	89.30	82.93	94.95	52.76
	'Basin R'	*'Boston'*	***'Dynamo'***	*'Enterprise'*	***'Jurassic'***	*'GSS 8529'*
	'Galaxy'	***'Dessert R78'***	*'Merit'*	*'GH 2042'*	*'Rustler'*	*'Jumbo'*
	'Garrison'	*'Dessert 82'*	*'Shinerock'*	*'GH 6225'*		*'Legend'*
	'GSS 1477'	*'SC 1036'*	*'Starshine'*	*'Jubilee'*		*'Madonna'*
	'Rocket'	*'GSS 5649'*	*'TOP 825'*	*'Kuatour'*		*'Mercur'*
	'Sweetstar'	*'Kinze'*		*'Prelude'*		*'Overland'*
		'Noa'		*'Puma'*		*'Rebecca'*
		'Sheba'		***'Royalty'***		***'Spirit'***
		'Tasty Sweet'				*'Turbo'*
		'Box R'				
		'Dessert R68'				

The individual factor weights of the individual sensory properties were determined in the course of the principal component analysis (PCA). The higher is the loading, the better is the characterisation of the 2D projection in the multi-dimensional space by the two principal components (**Figure 4.**).

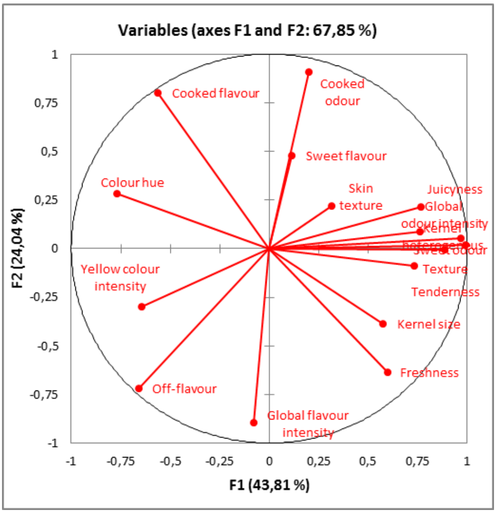


Figure 4. PCA loading values of the sensory properties of the sweet corns tested

4.1.2. Evaluation and monitoring by the expert panel

The basis of the sensory sciences is the sensory measurements. The sensory science uses the human senses as tools for the measurements. The quality of the sensory data is determined by the sensory panel and its members; therefore, their performance shall continuously be monitored. The expert panel consensus can continuously be followed, if the SRD method is repeatedly run using the normalised SRD values for each panellist. The panel tracking can be executed for arbitrary number of sessions (**Figure 5.**).

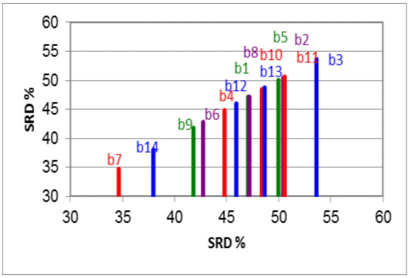


Figure 5. Rank of panellists determined by the SRDnorm values based on the results of 41 sessions in total

4.1.3. Results of the consumer hedonic tests

The interdependences between the sensory properties and the liking have been determined by Spearman-correlation. The total liking of the corn has a strong positive correlation with the liking of taste and the cooked taste. Furthermore, medium positive correlation is there in descending order concerning the liking of the sweet taste, tenderness, grain size and odour. The global taste strongly correlates with the cooked and sweet tastes, while a medium-strong positive correlation can be seen with the tenderness, hardness and odour *(Table 3.)*.

Table 3. Spearman rank correlation and p-values of the consumer liking

	odour	hardness	tenderness	kernel size	sweet taste	cooked taste	taste total	total
colour	**0.235**	-0.015	-0.018	0.057	-0.153	-0.061	-0.077	-0.031
odour	–	0.052	**0.296**	**0.183**	**0.197**	**0.274**	**0.253**	**0.306**
hardness	0.575	–	**0.359**	**0.275**	**0.389**	**0.452**	**0.363**	**0.391**
tenderness	**0.001**	**< 0.0001**	–	**0.319**	**0.435**	**0.585**	**0.487**	**0.524**
kernel size	**0.046**	**0.002**	**0.000**	–	**0.190**	**0.228**	**0.188**	**0.313**
sweet taste	**0.031**	**< 0.0001**	**< 0.0001**	**0.037**	–	**0.598**	**0.723**	**0.646**
cooked taste	**0.003**	**< 0.0001**	**< 0.0001**	**0.012**	**< 0.0001**	–	**0.769**	**0.750**
total taste	**0.005**	**< 0.0001**	**< 0.0001**	**0.040**	**< 0.0001**	**< 0.0001**	–	**0.896**
total	**0.001**	**< 0.0001**	**< 0.0001**	**0.001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	–

4.1.4. Results of the preference mapping

The preference maps determine the interdependence between the consumer liking of the quick-frozen sweet corn and the profile analysis results. The three clusters differ from each other in the order of preference determined by the evaluation of the liking of the corn *(Table 4.).*

Table 4. Hierarchy of the liking of the quick-frozen sweet corn species in an order increasing from the top downwards

Cluster 1	Cluster 2	Cluster 3
'Jurassic'	*'Spirit'*	*'Jurassic'*
'Spirit'	*'Dynamo'*	*'Dynamo'*
'Royalty'	*'Dessert R78'*	*'Spirit'*
'Dynamo'	*'Royalty'*	*'Dessert R78'*
'Dessert R78'	*'Jurassic'*	*'Royalty'*
'Galaxy'	*'Galaxy'*	*'Galaxy'*

In the preference maps, based on the overall liking, the liking is higher in the vicinity of the cluster centre and the longer the vector is, the more expressed the preference is. In case of the contour plot, the higher consumer liking in indicated with warmer colours. Within such warm colours, the more intense red colour shows higher liking. Therefore, it's worthy to position the species in the red fields of the preference maps (**Figure 6.**).

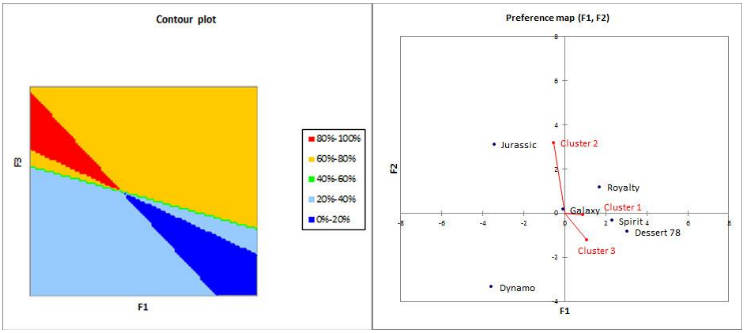
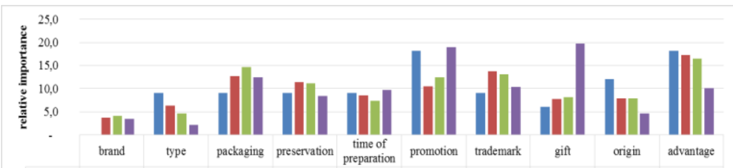


Figure 6. Preference map created by the summarised evaluation of the properties of the quick-frozen sweet corn species (F1-F2)

4.1.5. Sweet corn product optimisation

The conjoint analysis relies upon the assumption that the consumers – when making their shopping – aspire to maximise usefulness. The products purchased by them reflect their scale of values, the income, the social-demographic factors, etc. According to SCIPIONE (1994), the general results of the full-profile approach are as follows:

- relative importance value of the decision making factors, (**Figure 7.**)
- usefulness values of the product property levels *(Table 5.),*
- ideal product.



	brand	type	packaging	preservation	time of preparation	promotion	trademark	gift	origin	advantage
total	-	9,091	9,091	9,091	9,091	18,182	9,091	6,061	12,121	18,182
1 cluster	3,692	6,347	12,694	11,379	8,596	10,523	13,810	7,791	7,906	17,262
2 cluster	4,100	4,579	14,635	11,206	7,384	12,388	13,091	8,198	7,898	16,522
3 cluster	3,536	2,149	12,409	8,458	9,705	18,925	10,329	19,769	4,668	10,052

Figure 7. Relative importance of the product properties of the conjoint analysis in total and in relation to the three clusters

Table 5. Usefulness values of the product levels of the conjoint analysis

Product attributes		Total		Cluster 1		Cluster 2		Cluster 3	
		mean	*st. dev.*	*mean*	*st. dev.*	*mean*	*st. dev.*	*mean*	*st. dev.*
brand	private label	-0.76	1.13	-0.44	1.88	-0.35	0.55	-1.42	1.17
	brand	0.76	1.13	0.44	1.88	0.35	0.55	1.42	1.17
type	normal sweet	1.83	1.13	3.60	1.88	0.55	0.55	1.46	1.17
	super sweet	-1.83	1.13	-3.60	1.88	-0.55	0.55	-1.46	1.17
packaging	100g	-1.39	2.12	-1.47	3.53	-1.09	1.04	-1.60	2.20
	200g	1.07	2.12	3.11	3.53	0.47	1.04	-0.10	2.20
	400g	-1.45	2.12	-3.35	3.53	-0.97	1.04	-0.27	2.20
	500g	0.39	2.75	0.53	4.58	0.17	1.35	0.44	2.85
	1000g	1.37	2.75	1.17	4.58	1.42	1.35	1.53	2.85
preservation	canning (filled in bottle)	-0.47	1.96	-0.24	3.26	0.08	0.96	-1.27	2.03
	canning (filled in metal can)	-1.70	1.96	-3.14	3.26	-1.58	0.96	-0.49	2.03
	quick-frozen in plastic packaging	0.67	1.96	2.15	3.26	0.29	0.96	-0.28	2.03
	quick-frozen in paper packaging	1.50	1.96	1.23	3.26	1.20	0.96	2.06	2.03
time of preparation	ready to eat	-2.15	1.57	-3.09	2.61	-0.73	0.77	-2.68	1.62
	5 minutes	-0.64	1.57	-1.23	2.61	0.07	0.77	-0.81	1.62
	15 minutes	2.79	1.74	4.32	2.90	0.66	0.86	3.49	1.80
promotion	tablet/smart phone	0.51	2.12	0.05	3.53	0.33	1.04	1.06	2.20
	kitchen machine	0.48	2.12	-0.46	3.53	-0.23	1.04	2.04	2.20
	scooter	-0.41	2.12	1.10	3.53	-0.81	1.04	-1.45	2.20
	travel	0.99	2.75	1.50	4.58	1.21	1.35	0.29	2.85
	money	-1.57	2.75	-2.20	4.58	-0.49	1.35	-1.94	2.85
trademark	Excellent Hungarian Food	-3.66	1.96	-5.38	3.26	-1.64	0.96	-4.08	2.03
	Hungarian Product Grand Prix	0.94	1.96	2.08	3.26	-0.24	0.96	1.10	2.03
	Superbrands	-1.92	1.96	-4.29	3.26	-0.433	0.96	-1.27	2.03
	Hungarian Brands	4.65	1.96	7.59	3.26	2.32	0.96	4.24	2.03
gift	+10% gratis	1.34	1.57	1.86	2.61	1.19	0.77	1.10	1.62
	+25% gratis	-2.19	1.57	-2.70	2.61	-1.21	0.77	-2.708	1.62
	+33% gratis	0.85	1.74	0.84	2.90	0.02	0.86	1.60	1.80
origin	Hungary	-1.11	1.57	-0.28	2.61	-0.32	0.77	-2.68	1.62
	France	-0.79	1.57	-1.40	2.61	-0.59	0.77	-0.37	1.62
	Poland	1.90	1.74	1.68	2.90	0.92	0.86	3.06	1.80
nutritional advantage	natural fibre source	0.62	2.24	1.23	3.73	-0.33	1.10	0.99	2.32
	vitamin E source	4.51	2.95	9.42	4.90	0.25	1.45	4.21	3.05
	carotene source	-3.02	2.95	-4.92	4.90	-0.90	1.45	-3.29	3.05
	iron source	-0.75	2.95	-0.79	4.90	-1.07	1.45	-0.40	3.05
	vitamin B source	0.10	2.95	-0.10	4.90	0.48	1.45	-0.03	3.05
	GMO free	-0.07	2.95	-1.84	4.90	0.95	1.45	0.50	3.05
	organic	-1.38	2.95	-2.98	4.90	0.62	1.45	-1.97	3.05

4.2. Consumer prediction of the artificial neural nets

By means of the *"Best Net Search"*, the software has tested six MLFN (Multi Layer Feed forward Net) configurations to select the one providing the best fit prediction (**Figure 8.)** In case of the consumers, the 4-node MLFN was the one providing the best results (*Table 6.*).

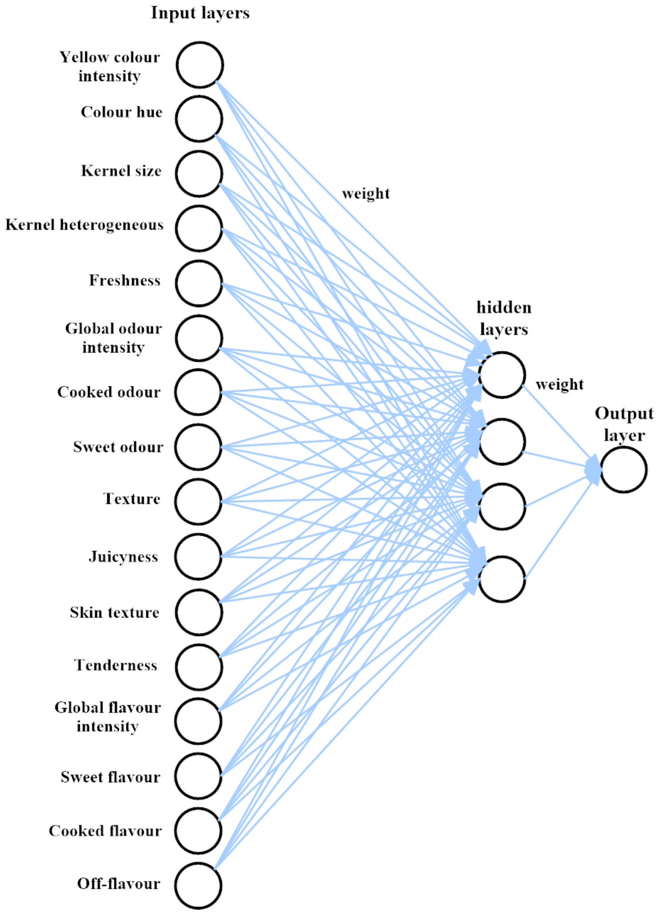


Figure 8. Interdependence of the artificial neural net (4 node MLFN)

Table 6. „Best Net Search" results of the network testing

Best Net Search	Minimum Residual (training)	Maximum residual (training)	Minimum residual (test)	Maximum residual (test)
MLFN 2 nodes	-1.06007	0.96618	-0.87118	0.99700
MLFN 3 nodes	-0.97762	1.03442	-0.88366	0.99625
MLFN 4 nodes	**-0.95308**	**0.96563**	**-0.88233**	**0.98695**
MLFN 5 nodes	-1.03178	1.0418	-0.98502	1.10380
MLFN 6 nodes	-1.11483	1.15705	-1.05110	1.14759

When training and testing the neural networks, the Palisade software is able to indicate the order of importance of the variables playing role in the structure of the networks as well.

4.3. Instrumental analytical results

The results of the instrumental measurements relating to the 41 species of quick-frozen sweet corn included in my research are contained in detail. Some results are emphasised, because for every samples the Kruskal-Wallis test was applied by calculating the exact p-value (α=0.05) then, the Dunn pair-wise post hoc test was carried out with Bonferroni correction.

4.3.1. Colour profile results

The colour differences between the individual species have been determined by comparing to the selected *'Royalty'* species used generally in the refrigeration industry and chosen during the expert profile. The colour differences were determined by the colour parameters (CIE L*a*b*) applying the Pythagoras-theorem *(Table 7.)*.

Table 7. Determining the perceivable colour differences (ΔE_{Lab*}) (reference 'Royalty')

0.5-1.5 hardly perceivable		1.5-3.0 perceivable		3.0-6.0 well perceivable		6.0-12.0 intensive	
Species	**ΔE_{Lab*}**	**Species**	**ΔE_{Lab*}**	**Species**	**ΔE_{Lab*}**	**Species**	**ΔE_{Lab*}**
'Puma'	0.8	*'Rustler'*	1.85	*'Tasty Sweet'*	3.1	*'Jubilee'*	6.0
'Enterprise'	1.1	*'Jurassic'*	2.06	*'Dessert R68'*	3.3	*'Box R'*	6.2
'Overland'	1.2	*'Prelude'*	2.23	*'Basin R'*	3.3	*'Turbo'*	6.4
		'Boston'	2.31	*'Merit'*	3.4	*'Kinze'*	6.4
		'Legend'	2.81	*'Madonna'*	3.5	*'Starshine'*	7.2
				'GSS 8529'	3.5	*'Noa'*	7.3
				'GH 6225'	3.9	*'Dessert R78'*	7.7
				'TOP 825'	4.1	*'GH 2042'*	9.9
				'Shinerock'	4.1	*'Garrison'*	10.5
				'Mercur'	4.4	*'Sheba'*	11.1
				'Dessert 82'	4.5	*'GSS 1477'*	11.1
				'Kuatour'	4.6		
				'GSS 5649'	4.8		
				'GSS 8529'	4.9		
				'Spirit'	4.9		
				'Rocket'	5.2		
				'SC 1036'	5.8		
				'Rebecca'	5.8		
				'Galaxy'	5.8		
				'Dynamo'	5.9		
				'Sweetstar'	5.9		

4.3.2. Texture profile results

The texture profile characterising the sweet corns shows a slow rising zone followed by a steep dropping section and the cycle was repeated. The second peak occupies nearly three-fourth of the first one representing the sweet corns according to the measurements. The measured texture profiles were identical for the individual samples, but in some cases the differences were significant (**Figure 9.**).

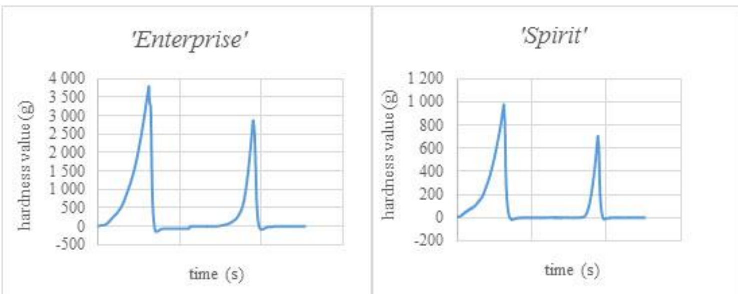


Figure 9. The *'Enterprise'* and *'Spirit'* texture profiles

4.3.3. Carbohydrate profile results

Analyzing the samples in general terms it can be seen that the glucose and fructose values are 8- 10 times lower than the sucrose values. Results of the carbohydrate measurement (glucose, fructose, sucrose) (**Figure 10.**).

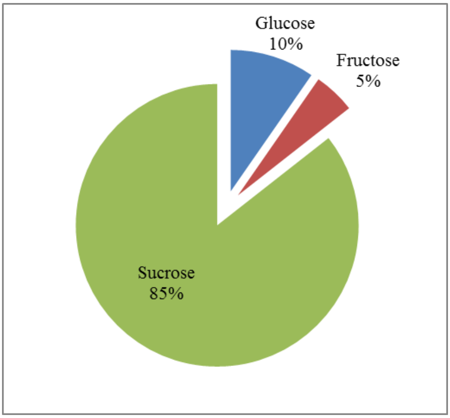


Figure 10. Results of the carbohydrate measurements

4.3.4. Results of the total carotenoid content

Based on the total carotenoid content, the *'Sheba'* species is significantly the highest one, while the species *'Legend'* and *'GH 2042'* have the significantly lowest values. The results for the remaining – identical – species were between these two groups (**Figure 11.**)

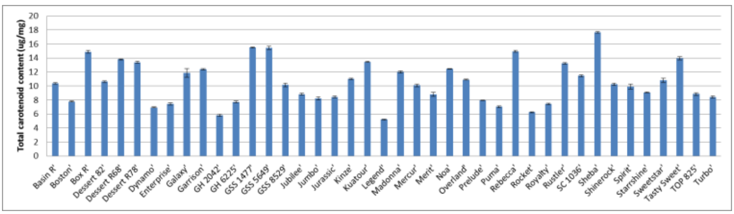


Figure 11. Total carotenoid content (µg/mg)

4.3.5. Results of the antioxidant capacity (DPPH, FRAP, TPC, ABTS)

Based on the DPPH, the *'Rebecca'* had the significantly highest value, while the significantly lowest one is the *'GH 2042'* species. Based on the FRAP, the *'Rebecca'* and *'Rocket'* species have the significantly highest value, while the *'Galaxy'* had the significantly lowest value. Based on the TPC, the species constituting the *'Turbo'*, *'Galaxy'*, *'Noa'*, *'Madonna'* group have the significantly highest value, while the significantly lowest values characterise the *'GSS 5649'* and *'Garrison'* species. Based on the ABTS, the significantly highest value was tied to the *'Dynamo'*, species, while *'GH 6225'* had the significantly lowest value. The smallest differences between the individual species were found by the ABTS method.

4.3.6. Results of the dry matter content measurement

During the ripening, the sweet corn transforms the starch into carbohydrate. The dry matter content of the sweet corn depends first of all on the quantity of carbohydrate and starch in the corn, because these are the textures being present in the grain in the highest quantities (**Figure 12.**).

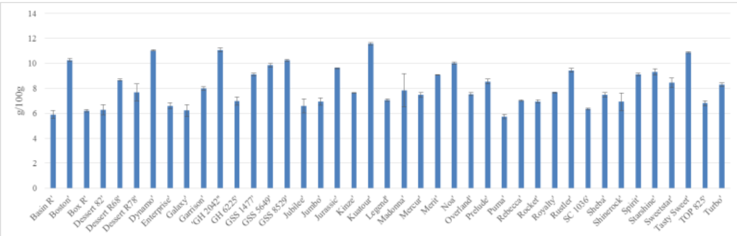


Figure 12. Dry mater content (g/100g)

4.3.7. Fumonisin and zearalenon micotoxin results

Before the sensory evaluation, the micotoxin quantities contained in the sweet corn were determined. Respecting the micotoxin content, the quantity of the zearalenone was below the detection threshold, while the amount of fumonisin failed to approximate the limit value of 4000 µg/kg, it remained below 70 µg/kg.

5. NEW SCIENTIFIC RESULTS

1. My research was the first one to characterise the full sensory profile and sensory clusters of 41 species of quick-frozen sweet corns. The colour, texture and carbohydrate profiles (glucose, fructose, sucrose) and antioxidant textures of the species were determined.
2. I certified first that the application of the repeated SRD method (Sum of Rank-Difference) run on the SRDnorm values provides a reliable hierarchy for the process of the series of sessions to evaluate and follow the individual panellist consensus.
3. I created first the odour, hardness, sweet taste, cooked taste and tenderness preference maps for the species by combining the professional sensory profile and the consumer acceptance tests.
4. Concerning the sweet corn, I determined firstly the comparative importance of the consumer decision making factors, the usefulness of the product levels and the ideal product combination by conjoint research. By combining the conjoint analysis with cluster analysis, I was able to explore and characterise the consumer segments.
5. I showed first the combination of the Monte Carlo simulation and the artificial neural networks was a good combination of methods to predict the consumer preferences by using the expert sensory data.
6. By means of the 4-node MLFN (Multi-Layer Feedforward Networks), optimized for the species and providing the best prediction, the product properties were identified and set in sequence by their importance. The most important variables were the sweet taste (18 %), the global colour intensity (14 %) and juicy (12 %).

6. CONCLUSIONS AND RECOMMENDATION

According to the literature, the profile analysis method is one of the most complex sensory tests; its advantage is that it well describes the properties/components of the tested products (ISO 11035:1994; VARELA and ARES, 2014). The sensory characterisation of all the 41 quick-frozen sweet corn species was shown in a profile diagram including an expert panel. The similarities and differences between the individual properties were analyzed by the one-way ANOVA, then, by using the pair-wise post hoc tests (Tukey HSD). It is advantageous to analyse the profiles describing the species and the sensory attributes by principal component analysis (PCA), and Bi-plot and to include several principal components, because this may provide a more complex outcome.

A well performing trained or expert panellist has good discriminative abilities, the results are absolutely reproducible and the scores given by him/her are near to the consensus point of the panel. The reliability of the results provided by the sensory panel are determined by the panellist performance parameters, i.e. their performance shall continuously be monitored (Bi and Kuesten, 2012; ISO, 11132:2012). My examinations have confirmed that the SRD method can be applied to the control of the profile data used to evaluate the performance of the sensory panellist.

I have proved at first that the repeated SRD method run with the SRDnorm values give a reliable rank for the entire series of sessions of the aggregate performance of the panellists. This rank can be defined for each evaluation, i.e. this method is suitable to the qualification of the panellist's performance. By means of the two-fold SRD run, the less reliable panellists can be identified; they can be trained by additional evaluations or excluded. From practical point of view, in the practice of the sensory evaluation it is worthy to choose a software being able to handle ties in the sequence of rank, because the panellists may specify the same values. The more lines we have, the probability of ties is higher in the sequence that may lead combinatorial explosion resulting in longer running times.

In relation to the preference mapping of the various foods, several international research projects were launched covering the entire food product group. Disregarding the colleagues of the Sensory Laboratory of Corvinus University of Budapest, no similar works were published concerning the sweet corn preference mapping (GERE et al., 2013; LOSÓ et al., 2012). In general terms, the preference maps are modelled by the overall liking. My results suggest that the species *'Galaxy'*, *'Royalty'* and *'Dessert*

R78' suit mostly the consumers' demands. Out of the three species the *'Galaxy'* proved to be the most preferred one. In my study, this species is the "most average" one created by the expert profiles, i.e. the other species of this cluster could be similarly preferred *'Basin R'*, *'Garrison'*, *'GSS 1477'*, *'Rocket'*, *'Sweetstar'*. The practical consequence is that the processors can substitute the *'Galaxy'* with these species to achieve similar sensory characteristics. In the case of newly bred species, following the creation of the expert profile, if it can be put into one of the clusters created during the research, the results of the preference map can be generalised to the new species as well.

Beside the preference map created by the overall liking, the preference maps of the quick-frozen sweet corns tested were also created (colour, odour, hardness, tenderness, grain size, sweet taste, cooked taste, global taste). By means of them the liking hierarchy by preference maps and clusters was created. These results indicate the parameters to be improved by the geneticists to produce even more popular species for the consumers.

The artificial neural networks presented and the approach combining the Monte Carlo simulation proved to be suitable for the prediction of the consumer preference according to the sensory expert panel. The advantage of this approach is that the time-, energy- and cost-consuming consumer examinations can be substituted by a prediction based on the expert data. I was able to predict the preference values of 36 sweet corn samples based on the consumer evaluations of six samples in total.

During the creation of the artificial neural network model, the product properties being the main drivers of the consumer acceptance were successfully identified. The hierarchy of importance is: sweet taste, global taste intensity and tenderness. These results are in harmony with the results of my preliminary research, by the extension of which reliable results could be obtained even for larger samples as well. This research could be extended to other horticultural products (e.g. pea) as well and use it for products, for which the consumer preference is not limited to a few, easily definable product parameters (e.g. apples). The results of the preference mapping originated from the overall liking coincide with the ANN results, because the *'Galaxy'* represents the cluster No. 1., while the *'Dessert R78'* the No. 2. and they have received the highest liking scores by the liking values of the prediction.

By means of focus group interviews taken with the consumers, the forms of thinking of the housewives purchasing quick-frozen sweet corns and the criteria of their selection influencing the process of the decision making were identified. By summarising the results of the 4 groups, the product parameters and product parameter levels being important from the point of view of sweet corn buying and representing the input information for the conjoint examination were identified. Using the conjoint test, the relative importance hierarchy, usefulness data and the ideal products were determined for the clusters.

Further research should be devised how the number of cards influences the quality of the answers. The goal of the orthogonal design is to decrease the number of variables under consideration of the expectable concentration abilities of the respondents. In my research, the high number of cards was reduced by the orthogonal block method. Based on my results, by analyzing the importance of the product parameters, I was able to show that independently of the consumer segments, the most important decision points declared are the nutritional advantages, promotion, the trademark and packaging. The least important factor in the consumer's decision is the selection of brand. The consumer clusters were characterised.

The species were characterised by the descriptive colour parameters (L*a*b*). The different target markets have various yellow colour preferences. It was experimentally confirmed that there was a demand on the consumers' side to know the corn's colour exactly. In industrial-scale sales (B2B), the exact determination of the yellow colour is missing from the specification in spite of the fact that the instrumental background of such specification is well known long ago. The colour differences between the species were determined as compared to *'Royalty'* applied mostly in the refrigeration industry and applied to the expert profile by using the spatial Pythagoras-theorem. Later, it could be used to the comparison of all species. A result like this could be of importance, because the outcome is based on visual difference classes.

The hardness of the sweet corns shows large variability. The characteristic texture profile was generally determined for the sweet corns, in which a fast dropping zone follows a slow upslope phase and this cycle is repeated. The second peak occupies nearly three-fourth of the firs peak; based on measurements, this is a property characterising the corn. No adhesion phenomenon was observed, i.e. the samples were not sticky or clammy.

The carbohydrates are decisive components of the sweet corns. A summary analysis based on research results confirms that the glucose and fructose values are 8-10 times lower in average than the sucrose level, in the sucrose content influences the sweet taste of the samples mostly. The super-sweet species contain sucrose in three or four-fold quantities as compared to the normal-sweet species.

The antioxidant capacity of the species was characterised by several methods (DPPH, FRAP, TPC, ABTS). Based on our results, the individual species have extraordinary antioxidant properties (*'Rebecca'* and *'Rocket'*). The TPC method did not reveal differences between the species which might originate from the fact that the carotenoides are responsible for the antioxidant content, not the polyphenols. The results of the micotoxin tests are extremely important from the point of view of food safety. The sensory tests were carried out after the negative outcome of such tests.

As one result of the examination, a working process was created which could serve as base to the further analysis of the sweet corn species. Examining the new sweet corn species improved in the course of the past years, they can become comparable by the above mentioned points.

PUBLICATIONS RELATED TO THE DISSERTATION

<u>Original Research Papers</u>

Published in referred (IF) journals:

1. **V. Losó**, A. Tóth, A. Gere, J. Heszberger, G. Székely, Z. Kókai, L. Sipos (2012): Methodolgy problems of the industrial perference mapping. *Acta Alimentaria,* 41 (Suppl) pp. 109-119. (IF=0,444).
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3. Gere, A., **Losó, V.,** Tóth, A., Kókai, Z., Sipos, L. (2012): Kukoricafajták preferenciatérképezése szoftveres támogatással. *Élelmiszervizsgálati közlemények,* 58 (3-4) pp. 118-130 (IF=0,04).
4. Gere, A., **Losó, V**., Radványi, D., Juhász, R., Kókai, Z., Sipos, L. (2013): Csemegekukorica fajták komplex értékelése. *Élelmiszervizsgálati közlemények,* 59 (3) pp. 120-134 (IF=0,04).
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6. **Losó, V.** (2009): A változó Japán zöldségpiaca. Hűtőipar, 57 (1) 6-9 p.
7. **Losó, V.** (2009): Japán értékesítési csatornák. Hűtőipar, 57 (3) 5-7 p.
8. **Losó, V**., Hegyi, A. (2010): Aromakerekek szerepe és jelentősége a termékfejlesztésben és a kutatásban, fontosságuk a Hűtőipar számára. 58 (3).

<u>CONFERENCE PUBLICATIONS</u>

International Conference Proceedings:

1. **V. Losó**, A. Gere, A. Györey, Z. Kókai, L. Sipos (2012): Comparison of the performance of a trained and an untrained sensory panel on sweetcorn varieties with the PanelCheck software. Applied Studies in Agribusiness and Commerce, (1-2) 77-83.
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5. **V. Losó**, A. Gere, A. Györey, Z. Kókai, L. Sipos (2011): Comparison of the performance of a trained and an untrained sensory panel on sweetcorn varieties with the PanelCheck software. Second AGRIMBA-AVA Congress, Dynamics of international cooperation in rural development and agribusiness, 22-24 june, 2011. Wageningen, Netherlands. 22. p.
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1. **Losó, V**., Kókai, Z., Füstös, Zs., Sipos, L. (2009): Csemegekukorica fajták számítógéppel támogatott érzékszervi vizsgálata. 2009. október 28-30. Lippay János – Ormos Imre – Vas Károly, Tudományos Ülésszak, p. 328-329. ISBN: 978-963-503-397-3
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3. Székely, G., Pecze, D., **Losó, V**., Sipos, L. (2009): Fenntartható zöldség- és gyümölcsfogyasztás hazánkban. Fenntartható fogyasztás – a növekedés határai konferencia, Szent István Egyetem, Gödöllő, 2009. március 27.
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7. Gere, A., **Losó, V.,** Györey, A., Szabó, D., Sipos, L., Kókai, Z. (2013): Élelmiszerek érzékszervi preferenciatérképezésének minőségbiztosítási szempontjai. HUNGALIMENTARIA – „Kockázatbecslés, önellenőrzés, élelmiszerbiztonság”, 2013. április 16-17.

Book:

1. Székely G., Sipos, L., Losó, V. (2009): FMCG marketing. Budapest, Aula Kiadó, B/5 713 p. ISBN 978-963-9698-73-4