THE INFLUENCE OF VARIETY AND SEASON ON CACTUS PEAR FRUIT QUALITY

De Wit, M; Rothman, M and Hugo, A

Department of Microbial, Biochemical and Food Biotechnology

University of the Free State, PO Box 339, Bloemfontein, 9300

E-mail: dewitm@ufs.ac.za

INTRODUCTION

- The adaptation of cactus pear (*Opuntia ficus-indica*) to arid and semi-arid climates allows them to be an interesting agricultural resource (El-Kossori *et al.*, 1998).
- It can be cultivated in areas that offer very little growth possibility for common fruit and vegetables (Saenz, 2000).
- Because it can withstand prolonged drought, it is considered as a potential alternative crop for drier regions (Duru and Turker, 2005).
- Fruit quality is highly influenced by environmental characteristics, such as climate and orchard management and may change from year to year (Inglese *et al.*, 2002; Ochoa *et al.*, 2006 and Mokoboki *et al.*, 2009).

AIM

- The objective of the study was to evaluate the effect of the following factors on cactus pear fruit quality:
- **Cultivar**
- **Season**
- **Cultivar X Season Interaction**

MATERIALS AND METHODS

- ***Cactus pear fruit:***
- Waterkloof germplasm (Bloemfontein): 1 348 m.a.s.l.; 556 mm annual rainfall; 8 years old; fully randomised design, two replications of each treatment.
- Cultivars included 32 *Opuntia ficus-indica* spp. and 1 *Opuntia robusta* spp. (used as animal fodder), picked at 50% colour-break stage; two seasons: 2007 and 2008.
- *Opuntia ficus-indica* spp. included: R1251, R1259, R1260, Algerian, American Giant, Amersfoort, Blue Motto, Corfu, Cross X, Direkteur, Fresno, Gymno Carpo, Malta, Messina, Meyers, Morado, Muscatel, Nudosa, Ofer, Postmasburg, Robusta X Castillo, Roedtan, Roly Poly, Rossa, Santa Rossa, Schagen, Sicilian Indian Fig, Tormentosa, Turpin, Van As, Vryheid and Zastron.
- *Opuntia robusta* spp. included: Robusta.
- Physical / chemical analysis included: fruit mass, % pulp, TSS (°Brix), titratable acidity (TA) (% citric acid), pH, pulp glucose and pulp fructose content.
- Statistical analysis: Analysis of Variance (ANOVA) and Fischer multiple comparison test (XLSTAT).
- ***Fruit was evaluated over two agricultural seasons: 2007 and 2008.***

RESULTS AND DISCUSSION

- ***ANOVA:***
- Highly significant differences (at probability level $p<0.001$) were observed among the 33 different cultivars for all the tested attributes observed in both seasons (Table 1), indicating that genetic differences among cultivars have a significant influence on fruit quality.
- Highly significant differences existed for all of the attributes tested between the two seasons (2007 vs. 2008) (Table 1). This observation is a clear indication that seasonal changes, that is, the microclimate plays a significant role in fruit quality.
- The cultivar X season interaction was highly significant for all of the attributes tested (Table 1), indicating that cactus pear varieties will react differently to different environmental conditions.
- It is evident that not only the cultivar as well as agricultural season, but also the interaction between the cultivar and season had significant influences on fruit quality.
- These results are in accordance to results obtained by different authors, namely that fruit quality is highly influenced by environmental characteristics, climate (Inglese *et al.,* 2002) and orchard management and may change from year to year (Ochoa *et al.,* 2006; Mokoboki *et al.,* 2009).

RESULTS AND DISCUSSION

Treatment	Cultivar	Season	Cultivar X Season
Fruit mass (g)	p<0.001	p<0.001	p<0.001
Pulp %	p<0.001	p<0.001	p<0.001
TSS (°Brix)	p<0.001	p<0.001	p<0.001
Pulp pH	p<0.001	p<0.001	p<0.001
Pulp TA%	p<0.001	p<0.001	p<0.001
Pulp Glucose (mg/g)	p<0.001	p<0.001	p<0.001
Pulp Fructose (mg/g)	p<0.001	p<0.001	p<0.001

RESULTS AND DISCUSSION

- ***Influence of cultivar on fruit quality (mean values):***

- **Fruit mass** (Table 2):

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding fruit mass, not only in 2007, but also in 2008.

  Mashope (2007) concluded that certain varieties naturally produce larger fruit and that fruit mass must be genetically controlled.

- **Pulp %:**

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding pulp %, not only in 2007, but also in 2008.

  This variation between the cultivars grown in Limpopo and the cultivars from the present study grown in the Free State may be due to the different agro-ecological environments.

- **TSS:**

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding pulp %, not only in 2007, but also in 2008.

  A high variation in the TSS content from the present study was observed for cultivars grown in the Limpopo province (Mashope, 2007). A possible explanation for this variation may be due to the difference in agro-ecological conditions between the two regions.

Table 4.2 Mean values for attributes of cultivars for season 2007 and season 2008

Cultivar X Year	Fruit mass (g) 2007	Fruit mass (g) 2008	% pulp 2007	% pulp 2008	TSS (°Brix) 2007	TSS (°Brix) 2008	%TA pulp 2007	%TA pulp 2008	TSS/TA 2007	TSS/TA 2008	Pulp pH 2007	Pulp pH 2008	Pulp Glucose g/100g 2007	Pulp Glucose g/100g 2008	Pulp Fructose g/100g 2007	Pulp Fructose g/100g 2008
R1251	108.07	130.06	59.97	49.17	11.8	13.33	0.44	0.32	26.82	41.66	6.26	6.19	41.33	46.33	28.33	32.67
R1259	121.77	121.64	58.5	55.14	13.13	13.73	0.46	0.40	28.54	34.33	5.89	6.69	25.33	51	22.33	21
R1260	110.28	134.53	59.57	46.84	12.2	12.7	0.45	0.50	27.11	25.4	5.93	6.71	48	43.33	30	19.33
Algerian	88.51	134.6	66.98	53.66	10.33	12.07	0.64	0.51	16.14	23.67	5.4	6.87	31	34.67	28.33	35.33
American Giant	90.21	130.17	55.98	49.79	11.8	12.5	0.31	0.54	38.06	23.15	6.02	6.75	31	34.67	23	25.67
Amersfoot	109.91	119.49	47.1	42.14	12.83	13.3	0.69	0.55	18.59	24.18	5.21	5.85	34.33	30	28.33	29
Blue Motto	118.05	137.33	49.73	44.31	13.4	12.3	0.25	0.28	53.6	43.93	7.18	6.43	34.33	33.33	31	23.67
Corfu	70.42	73.35	43.42	36.06	13	9.87	0.32	0.24	40.63	41.13	6.83	7.55	30.33	40.33	18.67	23.67
Cross X	111.39	141.29	59.29	47.28	12.33	13.7	0.66	0.52	18.68	26.35	5.85	4.97	42.33	47	30.33	32.33
Direkteur	116.13	111.95	53.85	48.13	12.1	10.37	0.89	0.36	13.6	28.81	7.08	7.13	33	47.33	25.33	27
Fresno	91.11	91.11	49.25	49.25	13.8	13.8	0.36	0.38	38.33	36.32	5.34	6.79	44.67	47.67	29.67	18.67
Gymno Carpo	107.74	134.01	60	51.36	11.93	11.73	0.47	0.46	25.38	25.5	6.18	6.81	40.67	35	32.33	26.33
Malta	115.79	129.98	61.52	53.29	12.73	11.8	0.55	0.38	23.15	31.05	5.87	6.25	31.33	42.33	22.67	32
Messina	103.32	123.34	45.3	44.25	14.07	13.57	0.37	0.76	38.02	17.86	6.19	6.1	38	38.33	40.67	19.33
Meyers	106.85	124.25	59.81	53.81	11.87	12	0.65	0.41	18.26	29.27	5.12	6.56	34.67	35	24	28
Morado	100.21	84.31	61.14	45.4	11.77	10.4	0.77	0.45	15.29	23.11	6.09	6.26	37	29.67	24	32
Muscatel	72.55	138.5	36.2	48.75	10.87	14.87	0.80	0.28	13.59	53.11	6.35	6.77	28.33	36.33	25	32
Nudosa	171.87	173.25	56.46	43.12	10.6	9.63	0.42	1.01	25.24	9.54	6.55	5.38	32.67	53	30	44.33
Ofer	118.87	136.69	57.53	48.88	11.79	12.4	0.38	0.44	31.02	28.18	6.3	5.91	41.67	41.33	33.67	33.67
Posmasburg	137.9	137.4	53.01	49.03	12.93	13.33	0.56	0.45	23.08	29.62	6.34	5.88	30	30	26.67	26.67
Robusta	136.13	186.04	45.27	45.84	10.6	8.43	1.47	0.27	7.21	31.22	4.3	6.28	36.67	23.33	16.67	26
Robusta Castillo	94.44	118.66	58.44	55.13	10.73	13.7	1.40	0.48	7.66	28.54	5.55	6.77	18.67	19.33	26.33	13.67
Roedtan	95.05	108.78	57.25	50.9	9.4	11.83	1.12	0.34	8.4	34.79	5.32	5.81	36	37.67	28	25
Roly Poly	143.5	97.75	70.51	38.18	11.13	11.93	0.39	0.34	28.54	35.09	6.03	5.46	31	24.67	26.33	29
Rossa	108.03	109.72	59.14	56.28	10.73	11.87	0.92	0.37	11.66	32.08	5.33	6.48	37	35.33	26.33	31.33
Santa Rossa	124.06	142.55	61.4	59.85	12.33	12.57	0.77	0.21	16.01	59.86	5.42	6.31	42.67	42.33	30.67	31.67
Schagen	123.21	131.16	58.4	53.12	13.53	12.2	0.66	0.43	20.5	28.37	5.33	6.67	45.67	45.67	28.67	28.67
Sicilian Ind.Fig	101.32	101.32	58.47	58.47	11.9	11.9	0.60	0.50	19.83	19.83	6.13	6.13	40.33	40.33	31.33	31.33
Tormentosa	140.56	119.43	59.57	53.44	11.9	13.13	0.55	0.45	21.64	29.18	5.61	5.55	24.67	48	20.33	34
Turpin	109.84	121.51	59.45	55.06	12.23	14.37	0.53	0.57	23.08	25.21	5.66	5.98	47	37.67	30.67	23.67
Van As	105.09	129.1	61.84	52.48	13.3	13.23	0.45	0.18	29.56	73.5	5.87	5.81	30.33	38.67	23	24
Vryheid	121.43	125.65	50.57	52.19	12.73	14.73	0.42	0.22	30.31	66.95	6.35	6.71	33.33	51.33	30.33	40.33
Zastron	77.59	107.35	52.63	48.12	12.47	13.33	0.37	0.28	33.7	47.61	6.39	6.88	43.67	48.33	27.67	21
Average	110.64	124.32	52.66	52.47	12.07	12.49	0.61	0.48	19.79	26.02	5.92	6.33	35.67	39.25	27.29	28.06
Significance (p)	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
MSE	282.14		25.55		0.66						0.06		3.17		1.66	
LSD (0.05)	27.13		8.16		1.31						0.41		2.88		2.08	
CV	22.35		15.49		11.88						10.44		21.21		20.53	

RESULTS AND DISCUSSION

- ***Influence of cultivar on fruit quality (mean values):***

- **Pulp pH:**

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding pulp %, not only in 2007, but also in 2008.

- **Pulp TA:**

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding pulp %, not only in 2007, but also in 2008.

  De Wit *et al.* (2010) also found that % TA values obtained from cactus pear cultivars in Waterkloof-, Cradock- and Oudtshoorn regions in South Africa were higher than values between 0.05 % and 0.18 % reported for cultivars from Chile (Saenz, 2000) .

  This finding stated that the environment plays an important role in the % TA in cactus pear fruit from different cultivars.

- **Pulp glucose:**

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding pulp %, not only in 2007, but also in 2008.

- **Pulp fructose:**

  Statistically significant differences ($p<0.001$) were observed among the 33 different cultivars regarding pulp %, not only in 2007, but also in 2008.

RESULTS AND DISCUSSION

- ***Influence of season on fruit quality (mean values):***

- The weather conditions of the two seasons are represented in Table 3.
- The orchard under study was maintained under dry-land conditions, with rain as the only source of water.
- Climatic data was captured via an automatic weather station, 50 m from the site.
- Mean daily values for temperature (°C) and rainfall (mm) were summarized to monthly values.
- Temperature conditions, namely average temperature, maximum- and minimum temperature, did not differ significantly between the two growth seasons.
- However, there was a large difference observed in the rainfall measured between the two seasons.
- In 2008, rainfall was 91.1 ml more than that measured in 2007. The higher rainfall in 2008 had significant influences on some of the quality parameters tested (Tables 1 and 2).

RESULTS AND DISCUSSION

	Growth seasons					
Weather Conditions	January 2007	February 2007	Average	January 2008	February 2008	Average
Average temperature (°C)	24	24.3	24.15	22.9	20.5	21.7
Maximum temperature (°C)	32.3	32.9	32.6	35.8	32.5	34.15
Minimum Temperature (°C)	7.5	6	6.75	11.3	9	10.15
Rainfall (ml)	15.5	8.4	11.95	92.5	113.6	103.05

RESULTS AND DISCUSSION

- ***Influence of season on fruit quality (mean values):***

- **Fruit mass (Table 2):**

  Rainfall was significantly higher in 2008 (Table 3). Higher rainfall had a significant influence on fruit mass: the average value for the fruit mass of 2007 was 110.64 g and the average value of fruit mass for 2008 was 124.32 g.

  Mokoboki (2009) found that the decrease of fruit mass over two seasons might be due to low rainfall and temperature in the second season.

  The fresh weight of fruit and % pulp was significantly greater in Argentina with the higher rainfall at the end of the fruit maturation period (Felker et al., 2005).

  Mashope (2007) found that there was a decrease in fruit mass during a lower rainfall in the second season when two seasons 2000 and 2001 were compared. Higher rainfall cause an increase in fruit size and a higher % pulp content.

  These results are supported by findings of Karababa *et al.,* (2004) and Bekir *et al.,* (2006), who reported that size and weight of fruit is influenced by locality, season and environmental.

- **Pulp %:**

  The average pulp % is also influenced by the rainfall pattern during the growth season: the average pulp % for cultivars 2007 was 55.99 % and the value for 2008 was 49.28 %.

  The peel of the fruit determined the higher fruit mass in 2008 - the peel % is also influenced by the rainfall. In periods of higher rainfall during the growth season, fruit tend to store water in the peel, thus the increased % of peel and the decreased % of pulp, as was observed (Mokoboki, 2009).

RESULTS AND DISCUSSION

- ***Influence of season on fruit quality (mean values):***

- **TSS:**

  The relatively unchanged values in TSS can be explained by the almost constant temperatures in season 2007 and season 2008.

  Table 2 indicated that rainfall did not influence the TSS values, because of the small difference in average ºBrix value of season 2007 and 2008.

  Mashope (2007) found that TSS increased from 12.68 to 14.36 from season 2000 to 2001 due to lower rainfall in 2001.

  Cactus pear fruit grown in dry areas is sweater than those grown in humid areas (Modragon-Jacobs, 2001).

- **Pulp TA:**

  The average % pulp TA content for 2007 was 6.08 and the content for 2008 was 4.8.

  Rainfall in 2007 was significantly lower than rainfall in 2008 (Table 3).

  A possible explanation may be that the higher rainfall in 2008, which produced larger and heavier fruit, might have caused the sugars and acids to be more diluted.

- **Pulp pH:**

  The average pulp pH value of cultivars for 2007 is 5.92 and the value for 2008 is 6.33.

  As a result, the cactus pear cultivars in 2008 had a higher TSS value, higher glucose and fructose contents and a lower TA value. A linear relationship between TSS and pH was reported (Gregory *et al.,* 1993).

RESULTS AND DISCUSSION

- ***Influence of season on fruit quality (mean values):***

- **Pulp glucose:**

  The average glucose pulp content for 2007 was 35.67 mg/g and the content for 2008 was 39.25 mg/g.

  These are surprising results, since it would be expected that the glucose values should be lower in 2008, due to the higher rainfall.

- **Pulp fructose:**

  The average fructose content for 2007 was 27.29 mg/g and the average content for 2008 was 28.06 mg/g.

  These results showed that the average fructose content is stable when season 2007 and season 2008 are compared. These results also follow the same trend as was observed for the TSS content and glucose content.

RESULTS AND DISCUSSION

- ***Influence of interaction between the season and the cultivars (Table 1):***

- The influence of the interaction between the cultivar and the season (cultivar X season) were significant on all of the parameters tested, especially the parameters important for eating quality.
- Highly significant differences ($p<0,001$) were observed for fruit mass, pulp %, TSS, pulp pH, pulp TA, pulp glucose content and pulp fructose content.
- These significant differences are an indication of the influence of different season conditions on fruit quality, thus an indication that cultivars will react differently in varying weather conditions, such as rainfall and temperature.
- Varieties that are recommended for commercial cultivation in the Mokopane district of the Limpopo Province in South Africa are Gymno Carpo, Malta, Algerian, Morado, Meyers and Roedtan (Mashope, 2007).
- The cultivars with the highest/best values regarding physical / chemical parameters are highlighted (in Table 4) in an attempt to identify the cultivars which performed the best regarding eating-quality, during the two seasons 2007 and 2008.

RESULTS AND DISCUSSION

Parameter	Cultivar 2007	Value	Cultivar 2008	Value
Fruit mass (g)	*Nudosa*	171.87	Robusta	186.04
Pulp %	Roly Poly	70.51	Santa Rossa	59.85
°Brix	*Messina*	14.07	Muscatel	14.87
Pulp pH	Blue Motto	7.18	Corfu	7.55
Pulp TA (%) (lowest)	Blue Motto	2.54	Van As	1.82
Pulp glucose (mg/ml)	Turpin	47.00	*Nudosa*	53.00
Pulp fructose (mg/ml)	*Messina*	40.67	*Nudosa*	44.33

CONCLUSIONS

- Highly significant differences (at probability level $p<0.001$) were observed among the 33 different cultivars for all the tested attributes observed in **both seasons → indicating that genetic differences** among cultivars have a significant influence on fruit quality.
- Highly significant differences existed for all of the attributes tested between the two seasons (2007 vs. 2008) was observed. → This is a clear indication that **seasonal changes** plays a significant role in fruit quality.
- There was a large difference observed in the rainfall measured between the two seasons. The higher rainfall in 2008 had significant influences on some of the quality parameters tested.
- The different environmental conditions during growth season had a significant influence on all of the chemical parameters important for eating quality, namely fruit mass, pulp percentage, sugar content of pulp, as well as pulp TA and pH.
- The cultivar X season interaction was highly significant for all of the attributes tested → indicating that cactus pear **varieties will react differently to different environmental conditions**.
- It was evident that not only the cultivar as well as agricultural season, but also the interaction between the cultivar and season had significant influences on fruit quality.
- These results are in accordance to results obtained by different authors, namely that fruit quality is highly influenced by environmental characteristics, climate and orchard management and may change from year to year.
- **Nudosa** performed the best regarding **fruit mass, pulp glucose and pulp fructose.** **Messina** performed the best regarding **°Bx and pulp fructose** content, while **Blue Motto** had the **best acidity levels (pH and TA)**.

ACKNOWLEDGEMENTS

- Dr. Herman Fouche and the ARC for providing the cactus pear fruit.

- NRF and UFS Strategic Cluster 4 for funding.