Raspberry fruit quality changes during ripening and storage as assessed by colour, sensory valuation and chemical analysis

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Introduction

Health-beneficial constituents of red raspberry, a commercially important berry crop, are influenced by maturation stage and storage conditions. This work presents a comparison of physical, sensory and phytochemical data to describe fruit quality changes taking place during raspberry fruit maturation and post -harvest storage. This is of particular interest in order to define the right maturity stage for harvesting but also subsequent storage until consumption to obtain fruits with optimal phytochemical/sensory properties.

Methods

Raspberry plants (*Rubus ideaus L.* 'Glen Ample') were produced and cultivated in a greenhouse at a commercial grower's nursery on the west coast of Norway during the Spring 2011. Five berry colours along an assumed maturation gradient were identified according to the natural colour system (www.ncscolour.com) and used as a reference during the picking. Colours ranged from orange/red (colour 1), light red (colour 2), red (colour 3), dark red (colour 4) and dark red/ lilac (colour 5, Figure 1). After harvest, raspberry fruit were stored in a dark, cold rom (2-3°C) for 1 day or 8 days until subsequent physical (fresh), sensory and chemical analysis.

Figure 1: Colour Scale

Physical Analysis
Pull Force and Fruit Firmness

Sensory Analysis
Acidity, Sweetness, Freshness, Bitterness, Appearance, Taste

Targeted Chemical Analysis
Sugars, Organic Acids, Flavonoids

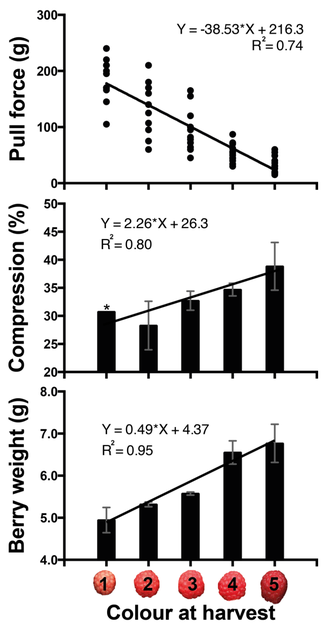

Figure 2 (A) Pull force. (B) Fruit Firmness. (C) Berry Weight) of *Rubus ideaus L.* at day of harvest for 5 different maturation stages.

Results

With increasing maturity level, both compression and weight also increase whereas the pull force required to detach the fruit from the receptacle decreases (Figure 2). The majority of anthocyanins and flavonols are increasing with increasing maturity level, while organic acids show the opposite trend, reflected in the strong negative correlations between both (Figure 3 and 4a). Storage conditions have an impact on the correlation where fruits stored for 8 days show partly weaker correlations(Figure 4b). Sensory results were correlated with the phytochemical results (Figure 5) The results revealed that visual appearance correlates significantly negatively with the majority of anthocyanins (r>0.75) and positively with some of the organic acids. On the other hand, the freshness trait has correlated positively with the organic acids contents (citric acid and oxalate) and negatively with sucrose and several anthocyanins, indicating a preference for lighter-coloured fruit for this trait. Sweetness correlates positively with the levels of sucrose and some anthocyanins. Furthermore, the sweetness trait correlates negatively with levels of oxalate.

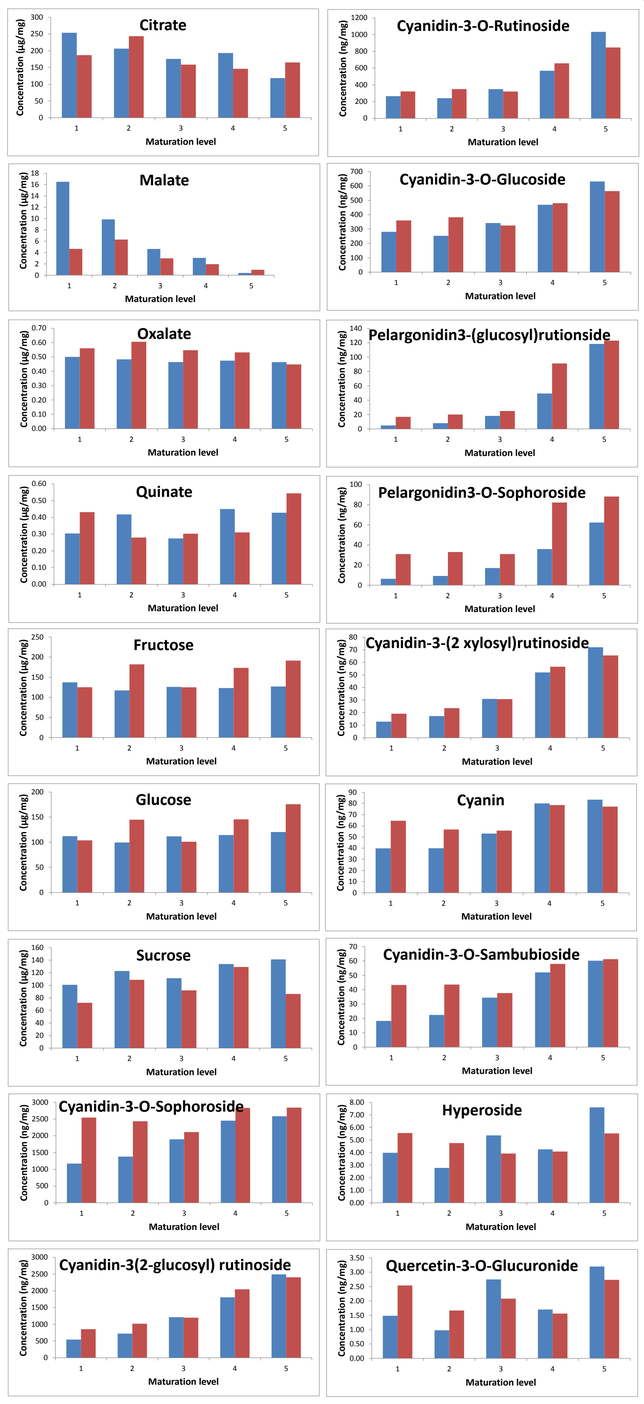

Figure 3 Graphical display of phytochemical concentrations in *Rubus ideaus* in dependence on maturation level. 1 day (blue), 8 days (red)

(a)

1 Day		OA				Sug.			Anthocyanins									FL	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
OA	1		0.91	0.90	-0.38	0.35	-0.53	-0.78	-0.75	-0.83	-0.84	-0.89	-0.83	-0.87	-0.87	-0.86	-0.85	-0.83	-0.81
	2	0.91		0.95	-0.47	0.47	-0.51	-0.83	-0.86	-0.94	-0.91	-0.90	-0.81	-0.83	-0.89	-0.77	-0.76	-0.67	-0.69
	3	0.90	0.95		-0.21	0.47	-0.40	-0.64	-0.67	-0.80	-0.76	-0.76	-0.65	-0.67	-0.73	-0.62	-0.61	-0.66	-0.76
	4	-0.38	-0.47	-0.21		-0.58	0.04	0.86	0.59	0.54	0.57	0.54	0.51	0.57	0.56	0.54	0.52	0.04	-0.14
Sug.	5	0.35	0.47	0.47	-0.58		0.50	-0.55	-0.14	-0.25	-0.20	-0.17	-0.01	-0.10	-0.15	-0.05	-0.01	0.24	0.19
	6	-0.53	-0.51	-0.40	0.04	0.50		0.36	0.76	0.70	0.74	0.76	0.83	0.76	0.76	0.75	0.78	0.85	0.78
	7	-0.78	-0.83	-0.64	0.86	-0.55	0.36		0.84	0.85	0.87	0.86	0.81	0.86	0.87	0.83	0.81	0.48	0.36
Anthocyanins	8	-0.75	-0.86	-0.67	0.59	-0.14	0.76	0.84		0.98	0.99	0.96	0.95	0.93	0.97	0.88	0.89	0.70	0.61
	9	-0.83	-0.94	-0.80	0.54	-0.25	0.70	0.85	0.98		0.99	0.97	0.92	0.92	0.97	0.85	0.86	0.71	0.68
	10	-0.84	-0.91	-0.76	0.57	-0.20	0.74	0.87	0.99	0.99		0.99	0.96	0.96	0.99	0.91	0.91	0.75	0.68
	11	-0.89	-0.90	-0.76	0.54	-0.17	0.76	0.86	0.96	0.97	0.99		0.98	0.99	1.00	0.96	0.96	0.82	0.74
	12	-0.83	-0.81	-0.65	0.51	-0.01	0.83	0.81	0.95	0.92	0.96	0.98		0.99	0.99	0.98	0.99	0.86	0.74
	13	-0.87	-0.83	-0.67	0.57	-0.10	0.76	0.86	0.93	0.92	0.96	0.99	0.99		0.99	0.99	0.99	0.83	0.71
	14	-0.87	-0.89	-0.73	0.56	-0.15	0.76	0.87	0.97	0.97	0.99	1.00	0.99	0.99		0.96	0.96	0.81	0.72
	15	-0.86	-0.77	-0.62	0.54	-0.05	0.75	0.83	0.88	0.85	0.91	0.96	0.98	0.99	0.96		1.00	0.86	0.72
	16	-0.85	-0.76	-0.61	0.52	-0.01	0.78	0.81	0.89	0.86	0.91	0.96	0.99	0.99	0.96	1.00		0.87	0.74
FL	17	-0.83	-0.67	-0.66	0.04	0.24	0.85	0.48	0.70	0.71	0.75	0.82	0.86	0.83	0.81	0.86	0.87		0.96
	18	-0.81	-0.69	-0.76	-0.14	0.19	0.78	0.36	0.61	0.68	0.68	0.74	0.74	0.71	0.72	0.72	0.74	0.96	

(b)

8 Days		OA				Sug			Anthocyanins									FL	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
OA	1		0.88	0.65	-0.26	0.20	0.04	-0.07	-0.58	-0.25	-0.40	-0.58	-0.33	-0.55	-0.61	-0.54	-0.47	0.29	-0.19
	2	0.88		0.91	-0.52	-0.22	-0.41	-0.08	-0.75	-0.49	-0.70	-0.87	-0.70	-0.81	-0.88	-0.85	-0.81	0.07	-0.33
	3	0.65	0.91		-0.80	-0.34	-0.56	0.19	-0.73	-0.57	-0.74	-0.86	-0.80	-0.79	-0.85	-0.87	-0.86	-0.31	-0.62
	4	-0.26	-0.52	-0.80		0.20	0.42	-0.61	0.54	0.54	0.54	0.49	0.63	0.48	0.46	0.57	0.61	0.81	0.90
Sug	5	0.20	-0.22	-0.34	0.20		0.97	0.50	0.52	0.67	0.75	0.67	0.79	0.69	0.65	0.68	0.72	0.17	-0.17
	6	0.04	-0.41	-0.56	0.42	0.97		0.35	0.65	0.75	0.85	0.79	0.91	0.80	0.77	0.81	0.85	0.28	0.04
	7	-0.07	-0.08	0.19	-0.61	0.50	0.35		0.27	0.26	0.33	0.33	0.22	0.38	0.35	0.26	0.23	-0.68	-0.88
Anthocyanins	8	-0.58	-0.75	-0.73	0.54	0.52	0.65	0.27		0.93	0.95	0.86	0.88	0.94	0.86	0.89	0.89	0.22	0.17
	9	-0.25	-0.49	-0.57	0.54	0.67	0.75	0.26	0.93		0.94	0.73	0.88	0.85	0.72	0.80	0.83	0.42	0.14
	10	-0.40	-0.70	-0.74	0.54	0.75	0.85	0.33	0.95	0.94		0.92	0.98	0.98	0.91	0.95	0.96	0.26	0.14
	11	-0.58	-0.87	-0.86	0.49	0.67	0.79	0.33	0.86	0.73	0.92		0.93	0.98	1.00	0.99	0.98	0.03	0.15
	12	-0.33	-0.70	-0.80	0.63	0.79	0.91	0.22	0.88	0.88	0.98	0.93		0.95	0.92	0.96	0.98	0.33	0.25
	13	-0.55	-0.81	-0.79	0.48	0.69	0.80	0.38	0.94	0.85	0.98	0.98	0.95		0.98	0.98	0.98	0.09	0.10
	14	-0.61	-0.88	-0.85	0.46	0.65	0.77	0.35	0.86	0.72	0.91	1.00	0.92	0.98		0.99	0.97	-0.01	0.13
	15	-0.54	-0.85	-0.87	0.57	0.68	0.81	0.26	0.89	0.80	0.95	0.99	0.96	0.98	0.99		1.00	0.15	0.22
	16	-0.47	-0.81	-0.86	0.61	0.72	0.85	0.23	0.89	0.83	0.96	0.98	0.98	0.98	0.97	1.00		0.22	0.25
FL	17	0.29	0.07	-0.31	0.81	0.17	0.28	-0.68	0.22	0.42	0.26	0.03	0.33	0.09	-0.01	0.15	0.22		0.76
	18	-0.19	-0.33	-0.62	0.90	-0.17	0.04	-0.88	0.17	0.14	0.14	0.15	0.25	0.10	0.13	0.22	0.25	0.76	

Figure 4 Correlation matrix phytochemical components of *Rubus ideaus* L. ('Glen Ample') stored for (a) 1 day and (b) 8 days at 2-3°C in the dark.

			Sensory Data						Sug/OA		
			Freshness	Sweetness	Acidity	Bitterness	Visual appearance	Taste	Brix	TA	Sugar:acid ratio
OA	Citrate	1	0.64	-0.22	0.52	-0.15	0.63	0.34	-0.47	0.81	-0.82
	Malate	2	0.25	-0.33	0.31	-0.10	0.38	0.14	-0.50	0.83	-0.80
	Oxalate	3	0.62	-0.64	0.75	-0.83	0.26	-0.49	-0.08	0.14	-0.15
	Quinate	4	-0.13	0.25	-0.13	0.53	-0.08	0.15	0.45	-0.02	0.10
Sug	Fructose	5	0.13	-0.13	0.16	-0.62	-0.15	-0.28	-0.30	-0.22	0.17
	Glucose	6	-0.10	0.18	-0.13	-0.39	-0.32	-0.14	-0.25	-0.44	0.38
	Sucrose	7	-0.69	0.72	-0.88	0.52	-0.53	0.36	0.25	-0.60	0.59
Anthocyanins	Cyanin	8	-0.36	0.53	-0.36	0.13	-0.62	-0.08	0.33	-0.80	0.78
	Cyan-Soph	9	-0.05	0.22	-0.04	-0.18	-0.38	-0.27	0.27	-0.70	0.68
	Cyan-Samb	10	-0.32	0.43	-0.32	-0.01	-0.57	-0.17	0.30	-0.83	0.80
	Cyan-Gluc-Rut	11	-0.67	0.60	-0.69	0.21	-0.76	-0.06	0.34	-0.92	0.90
	Cyan-Gluc	12	-0.59	0.55	-0.58	0.10	-0.68	-0.08	0.15	-0.78	0.75
	Pel-Soph	13	-0.47	0.21	-0.32	-0.20	-0.76	-0.45	0.28	-0.85	0.86
	Cyan-Xyl-Rut	14	-0.70	0.62	-0.72	0.25	-0.78	-0.03	0.35	-0.91	0.89
	Pel-Gluc-Rut	15	-0.76	0.43	-0.65	0.06	-0.83	-0.25	0.25	-0.86	0.86
	Cyan-Rut	16	-0.76	0.52	-0.70	0.15	-0.76	-0.11	0.17	-0.78	0.77
FL	Hyp	17	-0.40	0.28	-0.35	-0.04	-0.24	-0.09	-0.30	-0.35	0.27
	Querc-Gluc	18	-0.32	0.21	-0.27	0.02	-0.15	-0.09	-0.20	-0.33	0.26

Figure 5 Correlation matrix for phytochemical components with sensory characteristics.

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Conclusions

- Substantial chemical and sensory changes occur during final stages of maturation.
- Organic acid levels decrease during the maturation process while anthocyanins and sugars increase.
- Berries harvested at different developmental stages continue their development.
- Phytochemical content is in several cases strongly dependent on their maturity stage at harvest.
- Visual appearance is intrinsically linked to the maturity stage of the fruit.
- Oxalate and sucrose are driving phytochemical metabolites which significantly correlate with a wide range of sensory traits.