Effect of Fertilization and Training on the Sensory Properties of Kiwifruit in Orchards in Northern Portugal

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Abstrtact

In our latitude, expectations of the kiwifruit sector regarding kiwi productions with high yields and an adequate fruit size have been fulfilled. Thus, at present, this sector is focusing their efforts towards the quality improvement of fruit sensory properties, highly demanded by the consumer, so as to be competitive in the international market. There are several sensory properties that determine quality in kiwifruit. A kiwifruit is considered to have a good flavour quality standard, when the content rate of soluble solids (ºBrix) is the highest when consumed. Dry matter is another parameter internationally accepted as an indicator of the "intrinsic" quality of kiwifruit. The acidity and the starch content play an important role on the attainment of these quality standards. The aim of the present work is to determine the effect of fertilization and training (T- bar or pergola) on content and evolution of these sensory parameters. Assays were performed during 2007 in kiwi orchards in Northern Portugal (Kiwi Ibérica S.A.), taking fruit samples every two weeks from anthesis until harvest. Sensory properties of these fruits were analyzed according to AOAC methods. Results showed that training systems influenced significantly on dry matter, soluble solids, starch content and acidity. Significant differences were also observed between both fertilization practices during the first phases of fruit development; but these differences disappeared in later stages.

INTRODUCTION

In the last years, the worldwide increasing demand of kiwifruit has made producing countries to focus their interest towards the production of optimum quality fruits so as to be competitive in the international market.

For years, kiwifruit quality studies have been mainly based on morphological features of the fruit: standard size and shape, uniformity among harvested fruits, absence of defects on the skin, or even increasing number of fruits per plant. At present, apart for these aims, producers are focusing their interest towards the improvement of sensory properties that influence taste.

According to the European Commission Standard for kiwifruit (UNECE STANDARD FFV-46), to ensure an optimum quality and storage, kiwifruit must have attained a degree of ripeness at harvest of at least 6.2º brix or an average dry matter content of 15%, which should lead to 9.5º brix when entering the distribution chain.

Kiwifruit dry matter (DM) is mainly composed by carbohydrates (starch and sugars) and to a lesser extent by organic acids, proteins, lipids and minerals. Dry matter content at harvest is an important indicator of fruit quality, since it is related to sweetness of the

ripe fruit (Hall et al. 2006). Therefore, it is of crucial importance to understand the evolution of fruit dry matter until harvest.

As regards to starch, its accumulation starts in the fruit from 50 days after anthesis reaching its peak about 30 days before harvest, when hydrolysis of starch into sugar take place. Simultaneously, soluble solid concentration remains totally invariable around 4 to 4.5% (Beever and Hopkirk, 1990) until 90 days after the anthesis, when these levels start to increase (Hall et al., 1997) preparing the fruit for final consumption (Richardson et al., 1997).

Additionally, environmental conditions play an important role on kiwifruit composition. Thus, average DM content varies substantially from year to year and this variation is presumed to be linked to some aspect of climate (Beever and Hopkirk, 1990). According to Snelgar et al. (2006) this is mainly related with variations in temperature, being this the most important factor affecting intrinsic quality of the fruit.

Apart from environmental conditions, there are other factors such as cultural practices that significantly affect kiwifruit sensory parameters. Thus, soluble solids concentration varies depending on fruit load, its location in the plant (Hopkirk et al., 1986) and sun exposure (Ford, 1971; Davison, 1977); being the response more marked when plants are trained to T- bar systems than to pergola (Hopkirk et al.,1986).

At present, producers in North Western Spain and North Portugal, having fulfilled their expectations on yields, are focusing their interest towards the improvement of such properties to comply with current quality standards. The aim of the present work was to determine the effect of fertilization and training systems on content and evolution of some sensory parameters, namely fresh weight, dry matter, starch, soluble solids and acidity.

MATERIALS AND METHODS

The trial was conducted during 2007 in a mature commercial kiwifruit orchard (Kiwi Ibérica SA Lda) located in Valença do Minho in North Portugal. Planting design included rows of kiwifruit plants trained to Pergola system (P) and interrows trained to T-bar (T) and spacing 4*4.5 m (450 plantsha $^{-1}$).

Four treatments (A1P, A1T, A2P, A2T) were established. The basic maintenance treatment (namely A1) consisted on a splitted application of N, P, K, Ca and Mg by fertirrigation from week 1 to 8 after anthesis and on weeks 14 and 16, with a total of 40:30:40: kgha^{-1} of N:P_2O_5:K_2O plus 15 kgha^{-1} of CaO and 10 kgha^{-1} of MgO. For an alternative treatment (A2) kiwi plants were supplied with foliar application of NPK + calcium quelate on weeks 1, 2, 4, 6, 14 and 16 after pollination. The experimental lay out was a randomized block design with four replicates of twelve vines, with a total of 16 plots.

Anthesis (50% of the flowers were open) took place on 22 May. Sampling was initiated two weeks later (day 14 after the anthesis) until week 26 (day 182), every two weeks, collecting on each sampling date 10 fruits per plot. Analysis of variance was performed using the Duncan test at $p = 0.05$. Recommended date for harvesting was established, according to UNECE STANDARD FFV-46, when at least 6.2º Brix were attained.

Temperature and relative humidity were recorded every 10 minutes using a Hobo® Temperature Data Logger. Mean maximum, medium and minimum temperatures are shown in Figure 1.

In the laboratory, fruit diameters and fruit weight were measured and the corresponding analysis to determine sensory properties was performed. Dry matter content (%) was obtained by gravimetric determination (EN 12145: 1996);

concentration of soluble solids by refractometry (EN 12143: 1996) and results were expressed in º Brix; acidity in g of citric acid/100ml juice by potenciometry (EN 12147:1996) and starch content (%) by refractrometry (72/199/CEE).

RESULTS AND DISCUSSION

Fresh weight and fruit volume

Fruit fresh weight (FW) increased steadily and rapidly during the first 56 days after the anthesis in the four treatments (Fig. 2), reaching at this stage 60% of final FW; a similar percentage like that reported by Davison (1990). After this phase of growth, fresh weight increased slower from 56 to 154 daa - a week before the recommended date for harvest- at the same time starch progressively accumulated in the fruit. Similar data were recorded by several authors (Walton and Jong, 1990; Richardson et al., 2004).

The effect of treatments was significant 56 days after the anthesis, when statistically differences were observed between plants trained to Pergola and subjected to base and foliar fertilization (A2P) and plants on T-bar and subjected to base fertilization (A1T) , reaching respective weights of 60.9 versus 56.0 g. At harvest, FW of fruits from plants trained to Pergola was higher than fruits from T-bar and only those samples collected from T-bar vines supplemented with foliar fertilizer showed a proximate but lower FW (Table 1). These results agreed with those of Cook et al. (2004), who reported that T-bar structure was associated with a lower average weight of fruits, and differed from those attained by Smith et al. (1994), who accounted that Pergola system usually yielded more fruits of lower weight.

Dry matter

Dry matter content (DMC) increased exponentially from 42 to 140 daa, at the time fruit fresh weight increased very slowly (Fig. 2). Similar results were obtained by Hall, et al. (2006). No significant differences were observed among treatments from anthesis up to140 daa. However, a week before harvest plants trained to T-bar recorded dry matter rates significantly higher than plants to Pergola, although these differences were not observed between both fertilization treatments. At harvest, the highest concentration of DM was recorded in plants trained to T-bar with base fertilization.

Despite some authors have reported that temperatures may affect fruit DMC in certain growth stages (Richardson et al., 2004; Snelgar et al., 2006), in our study, the high temperatures recorded from 98 to 112 days after anthesis did not significantly increase DMC in the fruits.

Soluble solids

Soluble solid concentration (SSC) slightly increased up to 112 daa at the same time starch started to accumulate (Fig. 3). The increment on SSC content is more marked from 112 days until a week before harvest. In the same period starch begins to hydrolyze (140 days after anthesis). Results were similar to those obtained by several authors (Harman, 1981; MacRae et al., 1989; Beever and Hopkirk, 1990). Finally, SSC dramatically increased from 5º to º 6.2 Brix in one week, allowing fruit to be ready for harvest on day 154 daa, according to Standard quality requirements.

Differences were not observed among the four treatments from anthesis to a week before harvest. At harvest, the lowest SSC was recorded in plants on T-bar subjected to both base and foliar fertilization (A2T), differing significantly from rates obtained with the other treatments, as recorded in Table 1.

Starch

Starch levels in the fruit remained fairly constant from 0.2% to 0.6% during the 56 days after the anthesis (Fig. 3). Accumulation rate increased exponentially, reaching its peak 140 daa -20 days before the recommended date for harvest, when starch started to hydrolyze into sugars, descending its levels dramatically at harvest (160 daa). Results were similar to those obtained by several authors (Snelgar et al., 1993; Richardson et al., 1997; Ferrandino and Guidoni, 1999; Hall et al., 2006) although differed from those reported by Smith et al. (1992). The highest starch rate (3. 79 %) was obtained 140 daa on plants trained to T-bar.

It must be pointed out that starch accumulation stopped from 98 to 112 days after the anthesis, when maximum temperatures reached 30 ºC, only on plants trained to Pergola; thus, from 140 daa to harvest, plants trained to T-bar always presented higher starch content than plants to Pergola. It seems that T-bar plants were less influenced by these high temperatures. Several studies showed that high temperatures before harvest could delay hydrolysis of starch into sugars (Snelgar et al., 1993).

In relation to fertilization practices, treatment supplemented by foliar fertilization scored lower rates of starch than base fertilization from the onset of starch hydrolysis (140 daa) until harvest (160 daa).

Titratable acidity

Titratable acidity steadily increased during fruit growth up to 98 days after anthesis (Fig. 4), with similar results recorded by Ferrandino and Guidoni (1999). Acidity levels then remained constant up to 112 days after the anthesis, which may be related with the high temperatures reported at that time. Titratable acidity attained its peak 140 daa, which coincided with maximum starch accumulation, as it was also reported by Beever and Hopkirk (1990). Highest rates of titratable acidity varied slightly among treatments and ranged from 1.42 to 1.50 %. Our results coincide with those recorded by González (1991) in our environmental conditions, and are slightly higher than the levels of 1.3-1.4% commonly obtained in New Zealand (MacRae et al., 1989; Marsh et al., 2004). Some authors state that higher rates could be related to fruit sweetness and flesh firmness when consumed.

CONCLUSION

As a general rule, in our experimental conditions plants trained to Pergola yielded fruits of higher fresh weight, but lower rates were reached in sensory parameters such as starch and soluble solids in kiwifruits at harvest. In addition, there was a negative response to additional foliar application resulting in fruits with lower levels of dry matter, starch accumulation and titratable acidity.

Temperature peak reported in our study caused a stop on the evolution of fresh weight and every sensory parameter, except dry matter. Given the influence temperatures may have played in these quality parameters, our work need to be tested in further years, in order to create a model of the evolution of these sensory parameters, which undoubtedly will help us to improve these quality parameters of crucial importance for the market.

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Table 1. Fresh weight (g), dry matter (%) and solubles solid (ºbrix) contents of 'Hayward' Kiwifruit in plants trained to pergola (P) and T-bar (T) system with base (A1) and foliar fertilization (A2).

	treatments		Days after anthesis			
			126	140	154	168
Fresh weight (g)	A1	P	87,4 a	91,0 a	99,4 a	95,8 a
	A1	T	80,4 b	82,2 b	90,9 b	89,3 ab
	A2	P	93,6 a	94,9 a	99,4 a	95,5 a
	A2	T	90,0 a	88,1 ab	96,1 ab	88,9 b
Dry matter (%)	A1	P	15,15 a	15,70 a	15,93 b	16,65 b
	A1	T	15,57 a	16,04 a	16,56 a	17,19 a
	A2	P	15,17 a	15,70 a	15,72 b	16,29 b
	A2	T	15,44 a	15,81 a	16,39 a	16,69 b
Soluble solids (º Brix)	A1	P	4,61 a	5,39 a	5,47 a	7,32 a
	A1	T	4,59 a	5,15 a	5,51 a	7,59 a
	A2	P	4,82 a	5,34 a	5,76 a	7,58 a
	A2	T	4,75 a	5,18 a	5,61 a	6,84 b

Significantly different treatment means are indicated by different lowercase letters (Duncan test, $p<0,05$)

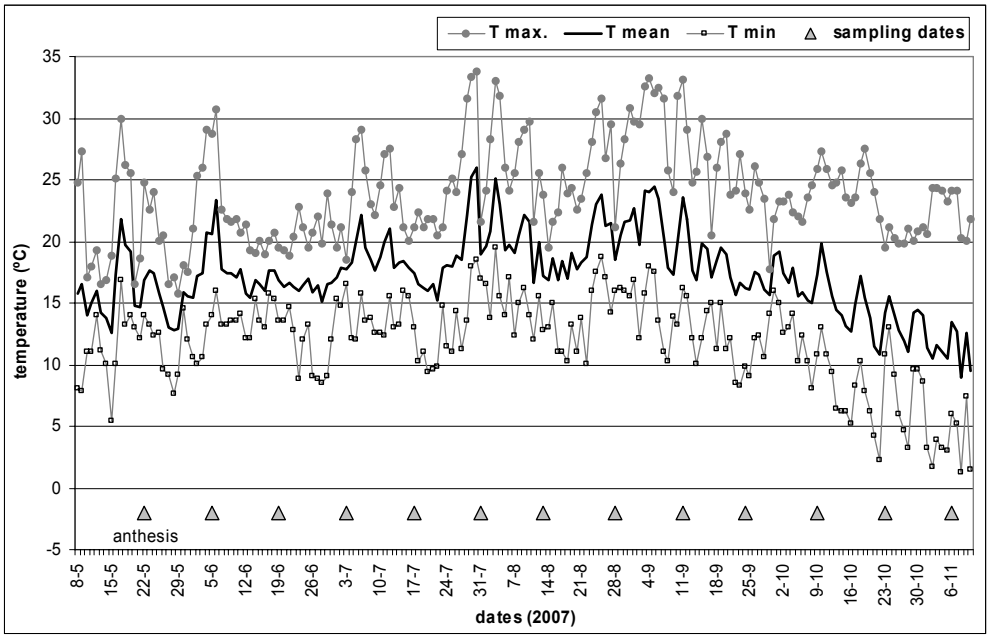

Fig. 1. Mean minimum, medium and maximum temperatures during the growth cycle in 2007. Data recorded by a Temperature Data Logger (Hobo®) *in situ* the experimental orchard.

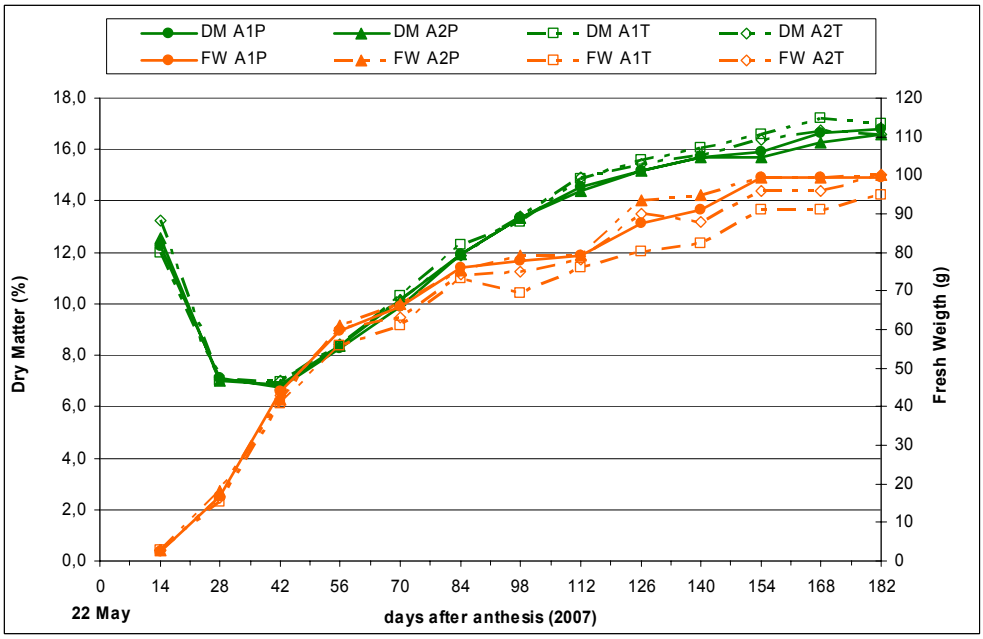

Fig. 2. Seasonal variation in dry matter (DM) in percentage and fresh weigth in Kiwifruit during 2007 (anthesis was recorded on 22 May). Open symbols refer to plants on T-bar; close symbols to Pergola. Square and circle symbols represent base fertilization (A1) and triangles and rhombus additional foliar fertilization (A2). Each point is the mean of eight replicates of ten fruits.

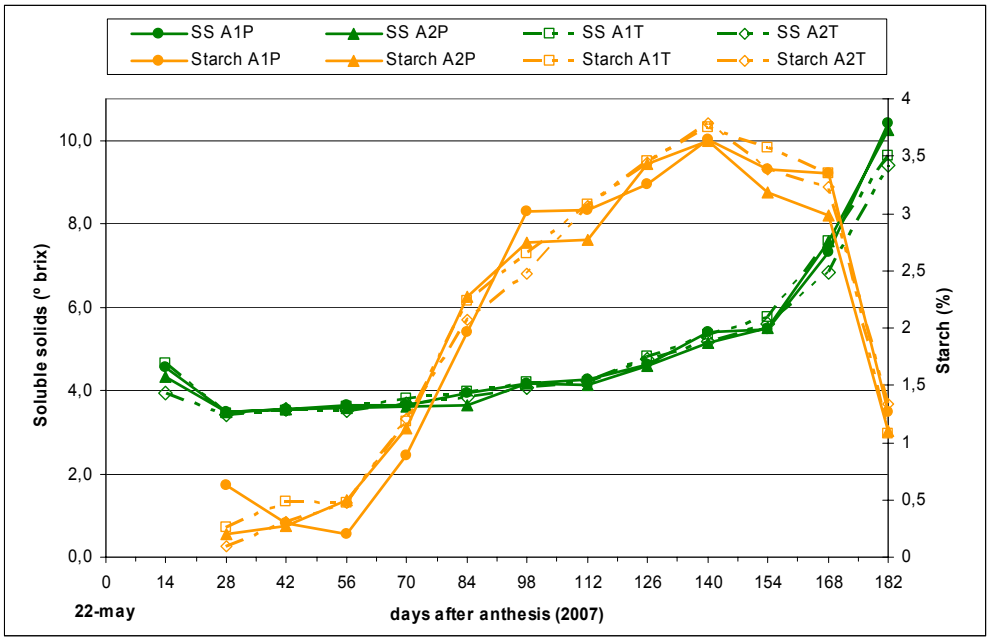

Fig. 3. Seasonal variation in soluble solids (SS) in the juicie (º Brix) and Starch as a percentage of dry matter (%) in Kiwifruit during 2007 (anthesis was recorded on 22 May). Open symbols refer to plants on T-bar; close symbols to Pergola. Square and circle symbols represented base fertilization (A1) and triangles and rhombus additional foliar fertilization (A2). Each point is the mean of eight replicates of ten fruits.

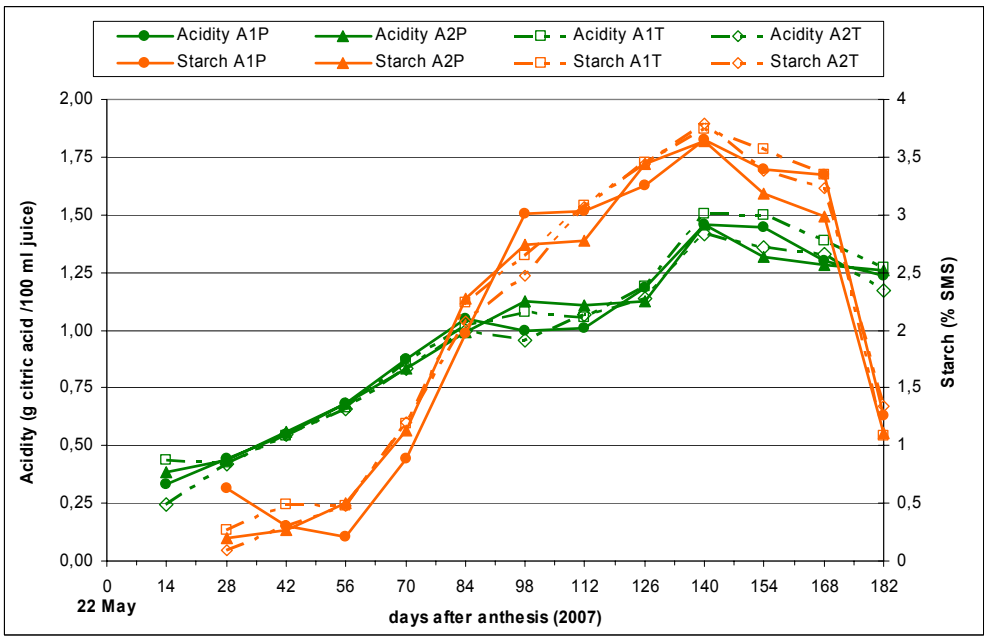

Fig. 4. Seasonal variation in acidity expressed in citric acid in the juice (g/100ml). Open symbols refer to plants on T-bar; close symbols to Pergola. Square and circle symbols represent base fertilization (A1) and triangles and rhombus additional foliar fertilization (A2). Each point is the mean of eight replicates of ten fruits.