

Handling Preripened California Plums

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I am receiving several phone calls and/or visits from growers, shippers and retailers about preripening and quality attributes of plums. Although the state of knowledge is not completed, I feel it is better to share what we know rather than accept what is being proposed by other groups. My proposed maturity (harvest) and quality (arrival) indexes are based on my current state of knowledge and are proposed with the main goal to increase California plum acceptance and consumption. We understand that orchard and environmental conditions affect quality attributes, and thus the proposed indexes.

When you are selling preripened plums for your stores/consumers, you will be offering your consumers tasty plums that are close to the ripe stage that have been specially harvested and handled to improve flavor and to delay gel breakdown, flesh browning, and mealiness. When preripening treatments are applied correctly and plums are handled according to this protocol, these plums will be at a higher stage of ripeness (juicy and tasty) and with a longer market life than conventionally packed product. For this reason, the plums need to be handled carefully at the retail store level. In our previous work we found that all of the plum cultivars tested were susceptible to chilling injury (CI) when stored at 41°F (Table 1). 'Blackamber', 'Fortune', and 'Angeleno' plums did not develop CI symptoms when stored at 32°F during a 5 week storage period. Market life of 'Blackamber', 'Fortune', and 'Angeleno' plums at 32°F was at least 5 weeks. In all plum cultivars, longer market life was achieved when stored at 32°F than at 41°F. However, market life potential is affected by several other factors such as orchard factors and maturity. For example, the role of maturity in market life potential is well illustrated in our 'Blackamber' plum work (Table 2). The preripening process does not completely prevent gel breakdown, flesh browning, or mealiness, therefore, this product needs to be moved quickly throughout the marketing chain according to the potential market life at a given store temperature (Table 1).

Table 1. Plum cultivar classification according to fruit market life under two storage temperatures based on chilling injury symptom development.

Cultivar	Market Life (weeks)	
	0°C	5°C
Blackamber	5+	2
Fortune	5+	3
Angeleno	5+	3
Showtime	4	3
Friar	4	2
Howard Sun	4	3

Table 2. Market life of 'Blackamber' plums harvested on four different dates then stored at 0 or 5°C. (2002 season).

Harvest date	Firmness	SSC	TA ^z	Maximum market life ^y (weeks at 0°C)	Minimum market life (weeks at 5°C)
6/20/02	7.0	10.3	0.78	2 ^{2,3}	<2 ^{3,4}
6/26/02	5.1	10.8	0.47	5 ³	2 ^{3,4}
7/2/02	4.8	11.7	0.43	5 ³	3 ^{1,3,4}
7/8/02	2.8	12.3	0.33	5 ³	2 ^{1,3,4}

^z Titratable Acidity measured after ripening (2-3 pounds).

^y End of market life based on chilling injury (CI) determined when $\geq 25\%$ of the fruit became mealy¹ or leathery², or had flesh bleeding/browning³ or gel breakdown/translucency⁴. Superscript indicates limiting condition.

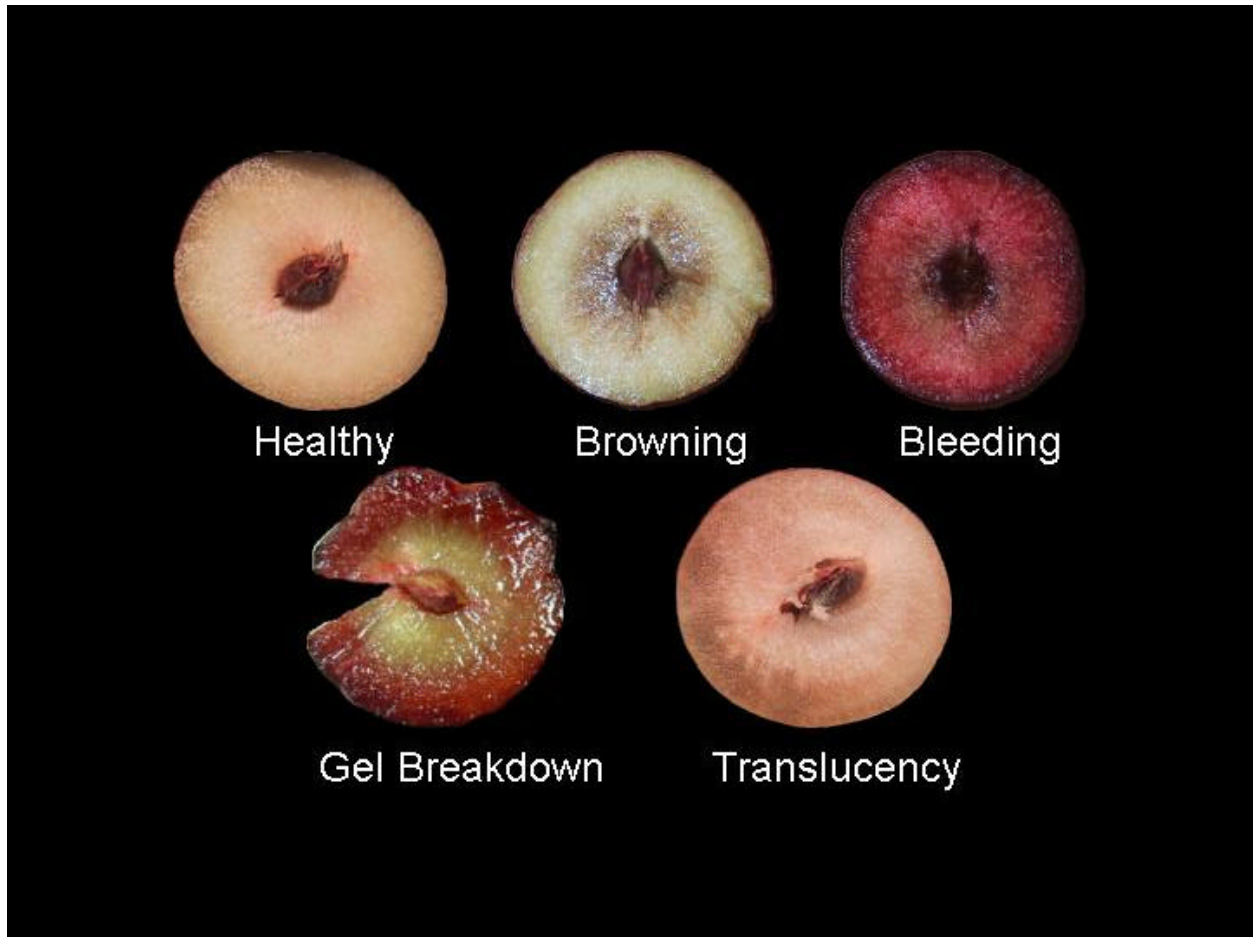


Figure 1. 'Blackamber' plum chilling injury symptoms observed during cold storage: flesh browning, flesh bleeding, gel breakdown, flesh translucency (overripe).

Our survey during 2003 and 2004 indicated that four main California companies were delivering 'Blackamber' plums within our proposed quality attributes (Table 3). This was reached by using a late harvest, good orchard management and the preripening protocol. However, in 'Fortune' plums, one out of the four companies was delivering 'Fortune' plums below our proposed 11%. In this case (source #4), plums were ripened but probably picked at low maturity or from a low quality potential orchard. This is a good example to illustrate that firmness by itself is not an accurate tool to define a high quality plum in a preripening program.

Table 3. Initial quality of 'Blackamber' and 'Fortune' plums, 2003 and 2004.

Blackamber Source	Red color (%)	Flesh firmness (lbf)				HSSC (%)	HTA (%)	HSSC:HTA
		Cheek	Tip	Suture	Shoulder			
1	80.8	5.8	6.3	6.1	5.8	11.6	0.81	14.5
2	88.8	5.0	7.2	6.3	6.0	10.7	0.74	14.8
3	86.0	6.8	8.1	7.3	6.9	11.9	0.67	17.7
4	93.5	5.6	6.4	6.4	6.2	10.6	0.90	12.0
Combined	87.3	5.8	7.0	6.5	6.2	11.2	0.78	14.7
Fortune Source	Red color (%)	Flesh firmness (lbf)				HSSC (%)	HTA (%)	HSSC:HTA
		Cheek	Tip	Suture	Shoulder			
1	75.2	8.4	9.6	8.6	8.0	15.9	0.83	19.1
2	70.7	7.4	7.8	7.9	8.9	11.7	0.78	15.0
3	73.2	7.9	8.5	8.7	8.2	12.6	0.72	17.7
4	73.3	3.8	4.9	3.8	4.0	9.5	0.44	21.6
Combined	73.1	6.9	7.7	7.3	7.3	12.4	0.69	18.4

Also, our previous work on impact bruising damage during harvesting and packaging (Crisosto et al., 2001) demonstrated that most plums cultivars with flesh firmness ≤ 3 lbf exposed to impact forces up to 245 G (simulating impacts occurring during rough packingline operations) were susceptible to bruising injury, but plums with flesh firmness >3 lbf were highly resistant to impact injury (Table 4).

Table 4. Minimum flesh firmness (measured at the weakest point on the fruit) necessary to avoid commercial bruising at three levels of physical handling.

Cultivar	Drop Height ^z			Weakest position
	(0.4") ~66 G	(2.0") ~185 G	(4.0") ~246 G	
Plums				
Blackamber	0	0	3 ^y	Tip
Fortune	0	0	0	Shoulder
Royal Diamond	0	0	0	Shoulder
Angeleno	0	0	0	Shoulder

^z Dropped on 1/8" PVC belt. Damaged areas with a diameter equal to or greater than 2.5 mm were measured as bruises.

^y Fruit firmness measured with an 8 mm tip.

Our transportation bruising damage work on white and yellow flesh peaches and nectarines indicated that packaging system and fruit firmness influence bruising damage occurring during transportation. In general, tray packed fruit tolerate transportation better than volume filled (Table 5). Fruit with firmness between 5-10 lbf

on the weakest fruit position only had between 3% (white flesh) to 10% (yellow flesh) damage. Our experience with plums suggested that plums will behave similarly to yellow flesh peach and nectarine cultivars or be even less susceptible to bruising damage during transportation.

Table 5. Incidence of bruising (impact + vibration) within three ranges of fruit firmness in packages of tray packed yellow flesh peaches, volume filled white flesh peaches, and volume filled yellow flesh nectarines after a 30 minute vibration treatment.

Packaging scenario/ bruise location	Percentage of bruised fruit at different levels of fruit firmness		
	<5 lbf	5 – 10 lbf	>10 lbf
Tray packed yellow flesh peach	35.1	2.7	0.0
Volume filled white flesh peach	55.2	13.6	--
Volume filled yellow flesh nectarine	43.9	9.8	4.4

At retail, bruising potential was measured by placing the instrumented sphere in the center of the top layer of a two-layer tray packed box (17-1/2" x 14" x 6-1/2" box, size 48 fruit). Accelerations (G) and velocity changes (m/s) were measured during box handling—removal from the pallet and repalletization. The mean force of impact measured was low at 19.1 G (SD = 9.2) with a velocity change of 0.94 m/s (SD = 0.36). The maximum force measured was 44.9 G and 1.57 m/s velocity change. Values were also low during movement of the fruit from the box to the retail display. The mean force of impact measured was 19.6 G (SD = 5.8) with a velocity change of 0.68 m/s (SD = 0.28). The maximum force measured was 34.7 G and 1.45 m/s velocity change. Our previous work demonstrated that most stone fruit can be safely handled at firmness of less than 6 lbf at the levels of impact measured above. Accelerations and velocity changes measured in boxes dropped from different heights were also lower than critical bruising thresholds for many plums with firmness equal to or higher than 3.0 lbf.

Table 6. Acceleration and velocity change values measured in the center position of the top tray of two-layer tray packed metric boxes dropped from different heights onto a solid counter top. Values given are means (\pm standard deviations).

Drop Height (inches)	Acceleration (G)	Velocity Change (m/s)
3	32.4 (\pm 3.0)	1.10 (\pm 0.02)
6	58.2 (\pm 4.2)	1.64 (\pm 0.06)
9	89.1 (\pm 2.7)	2.18 (\pm 0.13)
12	103.6 (\pm 11.6)	2.54 (\pm 0.21)

To reach maximum potential consumer acceptance, our sensory work over the last 5 years revealed that plum consumer acceptance reaches its maximum potential when

fruit have been ripened down to 2-3 pounds (80-90%), if fruit are consumed at a higher firmness (less ripe, 4-6 pounds) consumer acceptance is reduced from ~ 85% down to ~40% (Fig. 2).

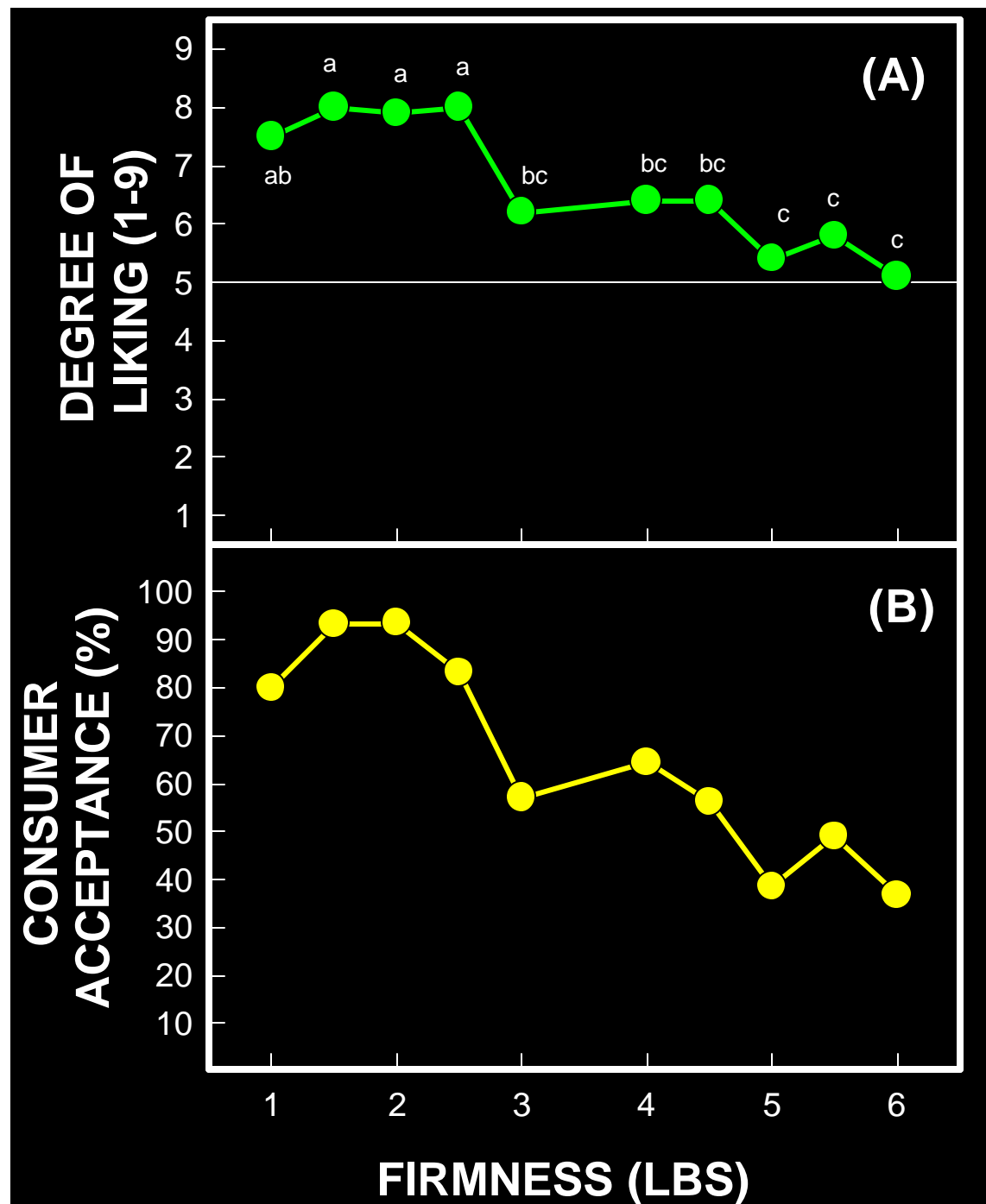


Figure 2. Relationship between 'Blackamber' plum flesh firmness and consumer acceptance.

Consumer acceptance of most traditional plums is related to SSC except for plums with high titratable acidity (TA) at consumption time as in some 'Blackamber' lots ($> 0.7\%$ TA). Same situation occurred in peaches and nectarines. In 'Blackamber' plum consumer acceptance and market life were highly dependent on harvest date. For fruit within the most common industry ripe soluble solids concentration (RSSC) range (10.0-11.9%), ripe titratable acidity (RTA) played a significant role in consumer acceptance. Plums within this RSSC range combined with low RTA ($\leq 0.60\%$) were disliked by 18% of consumers, while plums with RTA $\geq 1.00\%$ were disliked by 60% of consumers. Plums with RSSC $\geq 12.0\%$ had $\sim 75\%$ consumer acceptance, regardless of RTA. This work also pointed out that ripening before consumption decreased TA by approximately 30-40% from the TA measured at harvest (HTA). In some cases, this decrease in TA during ripening may increase the acceptability of plums that would otherwise be unacceptable.

Using "in store" consumer tests, we developed our proposed harvest maturity indexes based on firmness and minimum SSC for different plum cultivars. Based on our California and Chilean quality attributes surveys that we carried out over several years and our experience using these proposed harvest maturity indexes in California and Chile, I believe that the use of these standards can increase California plum consumption when applied carefully. For example our 3 year (1992-1995) harvest fruit quality survey that included SSC and firmness suggested that these indexes are reachable by our industry. For example in 'Blackamber' $\sim 80\%$ of the fruit will be equal or higher to our proposed 10.0% SSC and approximately 50% will exceed the 12.0% SSC. For 'Fortune' and 'Friar' more than 90% of the fruit will exceed our proposed 11.0% SSC and the same situation occurred with 'Angeleno' (12.0% SSC).

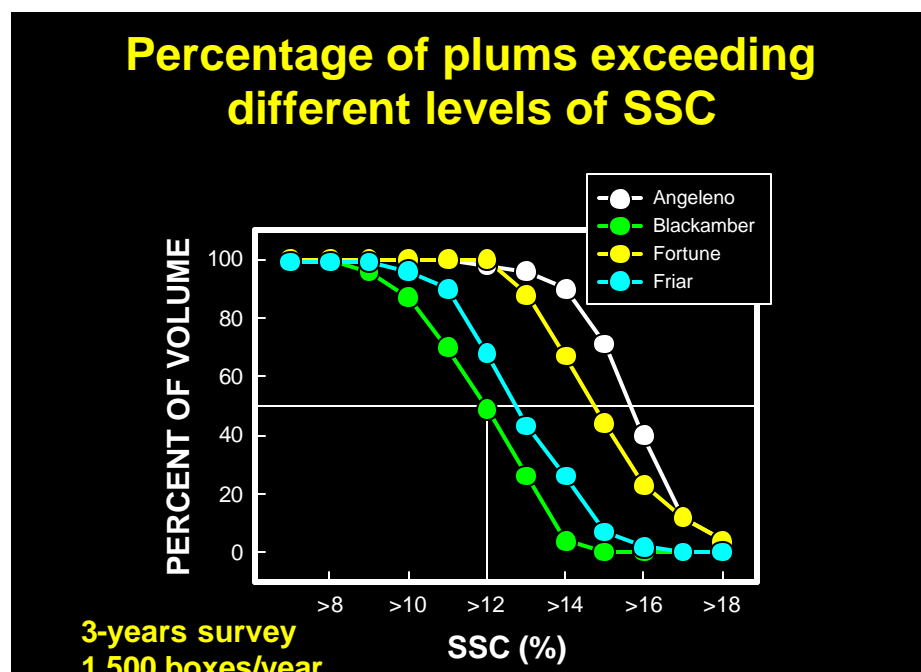


Figure 3. Percentage of plums exceeding different levels of SSC.

As most plum cultivars are well adapted to a late harvesting system, increase of SSC can be achieved without jeopardizing the crop (Table 2). We suggest the use of firmness as an indicator of how late to harvest (“Tree Ripe”) without inducing bruising, thereby maximizing orchard quality. But the decision of when to harvest should also take into account other factors such as fruit drop, environmental conditions, hand labor availability, market prices, distance to market, potential transportation damage, and temperature management at the receiving location.

Ideal plum ripening conditions are different than conditions for other tree fruits. In general, plums have a slower rate of flesh softening than peaches and nectarines (Table 7). At 50°F, plum ripening was slow enough to be considered negligible for many cultivars and rate of softening is still slow at 68°F for most cultivars. The best plum ripening can be accomplished when exposed to 77°F. During ripening, plum TA decreased, but the amount varied from cultivar to cultivar (Table 8). In general, plum TA tended to decrease ~40% when reaching the ripe stage (2-3 lb).

Table 7. Ripening rates of plums at 50°, 68° and 77°F measured with a UC firmness tester (8.0 mm tip).

Cultivar	Rate of Softening (lb per day)		
	50°F	68°F	77°F
PLUMS			
Black Beaut	0.6	0.6	0.9
Santa Rosa	0.3	0.6	0.8
Blackamber	<0.2	0.6	0.7
Fortune	0.4	0.9	1.3
Friar	0.3	0.6	1.3
Simka	0.8	1.2	1.7
Royal Diamond	0.3	0.5	1.1
Casselman	0.2	0.5	0.6
Angeleno	0.2	0.4	0.5
Average	0.4	0.7	1.0

Table 8. Titratable acidity of plums at harvest (mature), and after ripening at 68°F until the firmness of the flesh was less than 3 lbf (ripe).

Cultivar	Titratable Acidity (% malic acid)		
	Mature	Ripe	Change (%)
PLUMS			
Black Beaut	0.61	0.49	-19.7
Santa Rosa	1.12	0.45	-59.8
Blackamber	0.61	0.59	-3.3
Fortune	1.11	0.43	-61.3
Friar	0.98	0.41	-58.2
Simka	1.31	0.41	-68.7
Royal Diamond	0.54	0.34	-37.0
Casselman	0.70	0.46	-34.3
Angeleno	0.42	0.33	-21.4
Average	0.82	0.43	-40.4

Based on these facts and my experience, I proposed the following recommendations:

- Plum cultivars are well suited to late harvesting because of their low susceptibility to bruising damage during postharvest handling operations such as harvesting, packing and transportation. Thus, to maximize flavor, plums should be harvested when they reach a minimum SSC of 10-12% and a titratable acidity < 0.70% and be ripened at the shipping point prior to shipment.
- Our work suggests the use of firmness as an indicator of how late to safely harvest (“Tree Ripe”), however, the decision when to harvest should also take into account other factors such as fruit drop, environmental conditions, hand labor availability, market prices, distance to market, potential transportation damage, and temperature management at the receiving location.
- Plum cultivars are susceptible to chilling injury so they should be kept out of the killing temperature zone (36-46°F) during their postharvest life. Ideally, plums should be kept below 36°F during all of their postharvest handling, and should be marketed and consumed within their potential market life. This information provides guidance for growers, packers, shippers, handlers and retailers in designing their postharvest strategy to increase consumption.
- Plum ripening at the production site prior to shipment and proper handling at the retail end are both essential to allow consumers to perceive their potential taste.

Our proposed maturity (harvest) and quality attributes (retail) indexes are summarized below:

Table 9. Proposed harvest maturity indexes based on firmness (8.0 mm tip) and minimum SSC for different plum cultivars.

Cultivar	Firmness (lb)	Minimum SSC (%)
Blackamber	7-9	10-12 ^Z
Fortune	7-9	11
Friar	7-9	11
Royal Diamond	7-9	11
Angeleno	6-9	12
Betty Anne	7-9	12

^Z Blackamber plums with TA \leq 0.60% after ripening have a high consumer acceptance. If plums have \geq 12.0% SSC, TA does not play a role.

Table 10. Proposed plum quality attributes at the receiving point based on firmness (8.0 mm tip) and minimum SSC for different California plum cultivars.

Cultivar	Firmness (lb)	Minimum SSC (%)	Fruit Temperature
Blackamber	6	10	<36°F
Fortune	6	11	<36°F
Friar	6	11	<36°F
Royal Diamond	6	11	<36°F
Angeleno	6	12	<36°F
Betty Anne	6	12	<36°F

Tips for Handling Plums at Receiver End

At arrival, preripened plums should be cold (below 36°F) and with firmness (measured at any position on the fruit) of 4-6 pounds average ranging from 2 to 8 pounds in a given box. This firmness variability (2 and 8 pounds) in a given preripened box is standard due to natural fruit firmness variability. A fine tuning of this protocol is to evaluate the potential bruising damage of low firmness plums (2-3 lbf) under your specific handling situation. I believe it is more important to spend energy on following the protocol such as arrival temperature and minimum SSC rather than trying to have a uniform firmness in the box. My experience has been that consumers will eat the ripe fruit first (2-3 lbf) and wait the next three days to eat less ripe fruit 4-6 lbf). For example if they are buying 1 pound of plums (7 plums) and in this group there are plums with 2 to 6 pounds, they

will eat first the plums below 3 lbf. After 24-48 hours at room temperature, more plums from this group will be in the below 4 lbf ideal eating category. Even plums with 6 lbf at buying time (store) will be following in this desired ripe group.

Plum Store Display Suggestions

- Produce managers need to be educated about this new plum “Ready to Buy” type of fruit (preripened).
- Minimize mechanical damage and expedite an effective rotation (first in, first out).
- The dry tables should be labeled as preripened plums or “Ready to Buy/Eat” and consumers should understand that this fruit is riper than conventionally packed tree fruit.
- In order to protect preripened fruit, the display should be no more than two layers deep. In-box or clam shell display should be attempted.
- As plums will continue to ripen on the display warm/dry table, they should be checked often and the softest fruit be placed at the front of the display.
- Fruit that reaches the “Ready to Eat” ripeness of 2 to 3 pounds cheek firmness need to be sold quickly or placed in refrigeration to extend their shelf life.
- Consumers should be instructed that this type of fruit should be refrigerated if fruit are not going to be consumed within 3 days of purchase.

Tips for Handling Plums Once You Have Them at Home

- After purchasing fresh preripened plums at the grocery store, do not eat them until they are ripe (soft and aromatic) and do not put them in the refrigerator until they are ripe.
- The fruit looks nice in a basket or bowl on the countertop or table, or it can be placed inside a paper bag. It is ripe when it smells sweet and fruity and yields slightly to the touch. Ripe plums can then either be eaten or placed in the refrigerator to be eaten within the next 2-3 days.
- Putting hard fruit in the refrigerator before it is ripe exposes it to the “killing zone” temperatures between 36 and 50°, which stop the ripening process and ruin the fruit.
- If plums do not ripen properly, let your produce manager know.

I would like to acknowledge the economic and intellectual contribution of companies (Summeripe, Trinity Sales, Pacific Trellis, and PQA) which have the vision to increase plum consumption and help California growers by supporting our research program at the Kearney Agricultural Center.

More information on this subject can be found on the following websites:

- <http://www.uckac.edu/postharv/> and <http://postharvest.ucdavis.edu/>

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