RITA DE CÁSSIA MIRELA RESENDE NASSUR

INDICADORES DE QUALIDADE EM MANGAS DURANTE O AMADURECIMENTO

LAVRAS – MG

2013

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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ciência dos Alimentos, para a obtenção do título de Doutora.

Orientador

Dr. Luiz Carlos de Oliveira Lima

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À sociedade brasileira, pelos anos de ensino em instituição pública.

DEDICO

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RESUMO GERAL

Mangas são frutos climatéricos e mudanças metabólicas importantes ocorrem durante a maturação e amadurecimento, sendo algumas utilizadas como indicadores de maturação e qualidade. Avaliaram-se as mudanças durante o amadurecimento de mangas cultivar Ataulfo, Haden e Tommy Atkins e as correlações existentes entre parâmetros de qualidade do fruto maturo e maduro das cultivares Ataulfo e Tommy Atkins, visando a localização de indicadores de qualidade dos frutos. Frutos foram armazenados por 12 dias a 20°C. A taxa SST:AT aumentou durante o armazenamento para todas as cultivares. Mangas 'Ataulfo' e 'Tommy Atkins' apresentaram uma correlação muito forte entre matéria seca de frutos maturos e conteúdo de sólidos solúveis em frutos maduros (r=0.98 e 0.90). Frutos com maiores teores de matéria seca não influenciam o grau de aceitação em mangas cultivar Ataulfo, mas são mais aceitos em mangas 'Tommy Atkins'. Resultados indicam que matéria seca é um parâmetro estável durante o processo de amadurecimento do fruto e pode ser utilizado como indicador da qualidade final de consumo em mangas. Mangas provenientes do Brasil possuíam menor teor de matéria seca, com menor aceitação do consumidor, possivelmente resultado da colheita antecipada. Em um segundo experimento, características sensoriais e de qualidade de três cultivares de manga (Ataulfo, Haden e Tommy Atkins) foram avaliadas em três níveis de firmeza da polpa, visando à descrição do ponto final ou ideal de consumo. Utilizou-se análise sensorial descritiva (ADQ) para 14 atributos com 21 provadores treinados e avaliações de qualidade foram realizadas para melhor descrição dos frutos. Para a cultivar Ataulfo, amostras com menor firmeza receberam maiores notas para Suculência, Aroma Doce, Aroma Tropical e Gosto Doce, enquanto amostras mais firmes foram melhor caracterizadas por maior Mastigabilidade, Gosto Amargo e Firmeza. Amostras com maior firmeza de polpa em Haden foram caracterizadas pelo Gosto Amargo, Fibrosidade, Aroma de Citrus, Verde, Fermentado e de Pinus, mas não foram significativos para as diferentes firmezas nessa cultivar. Para a cultivar Tommy Atkins, somente os atributos de firmeza, suculência, mastigabilidade, Gosto Doce e Gosto Amargo foram significativos na avaliação dos três níveis de firmeza da polpa, de acordo com o P-valor. Mesmo quando amostras atingiram 7.84, 8.82 e 5.88N de firmeza para as cultivares Ataulfo, Haden e Tommy Atkins, respectivamente, apresentavam características desejáveis e o ponto final de consumo ainda não havia sido atingido, recomendando-se a venda e consumo.

Palavras-chave: *Mangifera indica* L. Qualidade de consumo. Matéria seca. Atributos sensoriais. Pós-colheita.

GENERAL ABSTRACT

Mangoes are climacteric fruit and important metabolic changes during ripening and maturation can be used as a quality and maturity index. Changes during ripening of mango stored at 20°C for 12 days were evaluated for ‘Ataulfo’, ‘Haden’ and ‘Tommy Atkins’ and correlations between quality parameters on mature and ripe fruit were evaluated for ‘Ataulfo’ and ‘Tommy Atkins’mangoes, aiming the evaluation of quality indexes. The TSS:TA ratio increased during storage, for all cultivars. ‘Ataulfo’ and ‘Tommy Atkins’ mangoes had a very strong correlation between dry matter (DM) on mature fruit and soluble solids content when the fruit is ripe (SSC) (r = 0.98 and 0.90). Fruit with higher DM content had no effect on degree of liking in ‘Ataulfo’ mangoes, but increased the degree of liking in ‘Tommy Atkins’ mangoes. According to the results, DM is a stable parameter throughout fruit ripening process that can be used to precisely predict the final consumer quality of mango fruit. Mangoes from Brazil have lower DM content, with lower consumer acceptance, possibly because of the early harvest. A second experiment was carried out to describe sensory and quality characteristics of three mango cultivars (Ataulfo, Haden and Tommy Atkins) on three flesh firmness levels during storage for a description of an ideal or final point of consumption. Sensory descriptive analyses of 14 attributes with 21 panelists and postharvest quality evaluations were carried out. ‘Ataulfo’ mangoes samples with lower flesh firmness received the highest notes for Chewiness, Sweet Aroma, Tropical Aroma and Sweet Taste. Firmer ‘Ataulfo’ mangos were better characterized by Firmness, Chewiness and Sour taste. Firmer flesh mangos on Haden cultivar were characterized by Sour Taste, while Fibrousness, Citrus, Green, Pinus and Permented Aroma were not significantly different for the three levels of firmness on this cultivar. On ‘Tommy Atkins’, only Firmness, Chewiness, Juiciness, Sweet Taste and Sour Taste were significant during sensory evaluation of the three flesh firmness levels, according to P-value. Even when samples were with 7.84, 8.82 and 5.88N of firmness for ‘Ataulfo’, ‘Haden’ and ‘Tommy Atkins’, respectively, desirable characteristics and attributes were present and the ending point of consumptions was not achieved, being sell and consumption recommended .

Keywords: *Mangifera indica* L. Eating quality. Dry matter. Sensory attributes. Postharvest

SUMÁRIO

PRIMEIRA PARTE

1 INTRODUÇÃO

A manga é um fruto cultivado em mais de 90 países, em regiões tropicais e subtropicais do mundo, tendo atingido a produção de 30 milhões de toneladas, em 2010 (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - FAO, 2013; THARANATHAN; YASHODA; PRABHA, 2006).

O Brasil está entre os dez maiores produtores e o segundo maior exportador mundial de manga (NOVAGRIM, 2013), com produção nacional de 1,2 milhão de toneladas e exportação de 124.694 toneladas, num total de 119.929.767 de dólares. Os estados de São Paulo, Bahia e Pernambuco são os principais produtores de manga no país, sendo os dois últimos responsáveis por 80% das exportações. Entre as cultivares de manga mais produzidas, está a cultivar Tommy Atkins, que representa cerca de 80% da produção brasileira (ANUÁRIO..., 2012).

Os Estados Unidos são o país que mais importa o fruto, responsável por 32% das exportações mundiais (EVANS, 2008; FAO, 2013), com frutos vindos, principalmente do México, Peru, Equador e Brasil. Nos últimos anos, o Brasil tornou-se um exportador significante de mangas para os Estados Unidos, competindo com o México no início e no final da estação (EVANS, 2008). Dentre os frutos importados, os das cultivares Ataulfo, Haden e Tommy Atkins destacam-se com o maior número (EVANS, 2008; FAO, 2013).

Um adequado manuseio dos frutos requer conhecimento de fisiologia pós-colheita e de práticas que possam ajudar a desenvolver e a manter frutos de alta qualidade (BRECHT; YAHIA, 2009; YAHIA; ORNELAS-PAZ; ARIZA, 2006). As práticas de pós-colheita utilizadas para mangas dependem do sistema e do local onde o fruto será vendido, incluindo fatores como distância ao mercado consumidor, expectativas dos consumidores, disponibilidade de mão de obra, tecnologia e infraestrutura (YAHIA; ORNELAS-PAZ; ARIZA, 2006).

Por serem frutos climatéricos, as mangas podem ser colhidas em sua maturidade fisiológica, mas não maduras (estádio verde-maturo) e armazenadas. O início do amadurecimento pode ser controlado por armazenamento refrigerado e por modificação da atmosfera (YAHIA; SINGH, 2009).

A cor da casca dos frutos pode variar entre verde, amarelo, laranja e vermelho, de acordo com a cultivar. Os frutos podem ser de diferentes formatos e com polpa de diferentes cores, de acordo com a cultivar e o estádio de desenvolvimento, sendo fonte de compostos antioxidantes, fibras, vitamina A e C; possuem baixo teor de gordura e conferem sabor e aroma característicos. A doçura e a suculência do fruto, assim como sua cor atrativa, fazem com que o mesmo seja muito apreciado pelos consumidores.

Assim, a caracterização do metabolismo de frutos de cultivares de mangas importantes no mercado brasileiro e para exportação permitirá maior compreensão das mudanças metabólicas que ocorrem durante o amadurecimento e melhor identificação de indicadores que poderão auxiliar na avaliação da qualidade final daqueles a serem oferecidos ao consumidor.

O estudo foi realizado com o objetivo geral de avaliar a qualidade físico-química e sensorial de cultivares de mangas durante o amadurecimento e os objetivos específicos foram: avaliar indicadores da qualidade final dos frutos (artigo 1) e proceder à avaliação de características sensoriais em frutos de cultivares de manga durante o armazenamento (artigo 2).

2 REFERENCIAL TEÓRICO

2.1 Mangas: importância e valor nutricional

Os frutos da mangueira são do tipo drupa, com casca (epicarpo) e mesocarpo comestível (polpa), que envolvem um endocarpo fibroso com uma única semente. Existem grandes diferenças em tamanho, forma, aparência e características fisiológicas entre as cultivares. Por exemplo, o peso médio de diferentes cultivares varia entre menos de 80 g e mais de 800 g (YAHIA, 2011).

É um fruto de grande importância, com produção global de cerca de 30 milhões de toneladas, em 2010 (FAO, 2013), sendo a segunda maior cultura tropical do mundo, depois da banana.

Mangas são fonte de Vitamina C e seu conteúdo diminui durante o amadurecimento, variando de 13 a 178 mg por 100 g de polpa do fruto, de acordo com a cultivar avaliada (SINGH, 1960). Vitamina B1, ácido fólico e carotenoides precursores da vitamina A também estão presentes nos frutos. Carotenóides, tais como β-caroteno, zeaxantina, violaxantina e neoxantina, já foram observados (ORNELAS-PAZ; YAHIA; GARDEA-BEJAR, 2008, 2010) e são pigmentos responsáveis pela coloração amarelo-alaranjada do exocarpo e do mesocarpo (VÁZQUEZ-CAICEDO; NEIDHART; CARLE, 2004).

A composição nutricional da manga é apresentada na Tabela 1.

Tabela 1: Composição nutricional de 100 gramas de polpa de manga baseada em análises realizadas com mangas cultivar Tommy Atkins, Keitt, Kent e ou Haden.

Nutriente	Unidade	Valor em 100 g
Água	g	83,46
Energia	kcal	60
Proteina	g	0,82
Lipídeos Totais (gordura)	g	0,38
Carboidratos por diferença	g	14,98
Fibra dietária total	g	1,6
Açúcares totais	g	13,66
Cálcio, Ca	mg	11
Ferro, Fe	mg	0,16
Magnésio, Mg	mg	10
Fósforo, P	mg	14
Potassio, K	mg	168
Sódio, Na	mg	1
Zinco, Zn	mg	0,09
Vitamina C, ácido ascórbico	mg	36,4
Tiamina	mg	0,028
Riboflavina	mg	0,038
Niacina	mg	0,669
Vitamina B-6	mg	0,119
Folato, DFE	µg	43
Vitamina B-12	µg	0,00
Vitamina A	µg	54
Vitamina E (alfa-tocoferol)	mg	0,90
Vitamina D (D2 + D3)	µg	0,0
Vitamina K	µg	4,2
Ácidos graxos saturados	g	0,092
Ácidos graxos monoinsaturados	g	0,140
Ácidos graxos polinsaturados	g	0,071
Colesterol	mg	0

Fonte: United States Department of Agriculture – USDA (2012)

Mangas são frutos ricos em antioxidantes, como os compostos fenólicos (ORNELAS-PAZ; YAHIA; GARDEA-BEJAR, 2007; YAHIA, 2010). A perda de adstringência durante o amadurecimento de mangas está associada com a diminuição do conteúdo de compostos fenólicos e o seu consumo tem sido associado com importantes benefícios à saúde (YAHIA, 2010).

2.2 Desenvolvimento e tratamento dos frutos

O desenvolvimento inicia-se com uma rápida multiplicação celular, durante cerca de 3 semanas, seguida por alargamento das células por, aproximadamente, 4 semanas. O tamanho máximo dos frutos é atingido de 10 a 28 semanas após o início da frutificação e coincide com a maturidade fisiológica. O teor de amido na polpa atinge o pico nesse ponto, seguido por um acentuado decréscimo no amadurecimento (TANDON; KALRA, 1983).

O momento da colheita é uma das mais importantes decisões visando à qualidade dos frutos da mangueira. Frutos colhidos antes da maturidade ideal podem amadurecer, mas haverá o desenvolvimento de sabor e aroma inferiores, aumentando a suscetibilidade ao *chilling*, caso sejam transportadas em temperaturas abaixo da mínima de segurança, tendo seu tempo de armazenamento reduzido.

Após a colheita, torna-se necessária a remoção do látex e, para isso, recomenda-se a colheita dos frutos com haste maior ou igual a 5 cm e, depois, o corte das mesmas na zona de abscisão, colocando os frutos com a haste para baixo para que o látex liberado não atinja a casca. No Brasil, é comum a prática de colheita de mangas com a haste maior e cautela no transporte para a casa de embalagem, onde a mesma será posteriormente cortada. Aproximadamente 24 horas após a colheita, o látex não mais escorrerá, mesmo que a haste seja cortada com menor tamanho.

Um ponto de grande preocupação na pós-colheita de mangas é a inspeção entomológica inicial, feita por um inspetor de órgão autorizado e de acordo com a legislação de cada país, retirando-se uma amostra para a verificação de infestação de mosca-das-frutas, cuidado especialmente dado aos frutos destinado à exportação. O tratamento com água quente é comumente utilizado na quarentena de mangas, no qual as mangas são imersas por, aproximadamente, 75 minutos em água, à temperatura de 46 °C (BRECHT; YAHIA, 2009). Devem-se utilizar somente frutos maturos, evitar o contato com o látex e fazer o uso de água potável. Após o tratamento, os frutos são resfriados, encerados, separados por tamanho e colocados em caixas adequadas para transporte e distribuição.

2.2.1 Mudanças durante a maturação e o amadurecimento

Como um fruto climatérico, mangas exibem padrão climatérico de respiração e aumento na produção de etileno durante o amadurecimento (BRECHT; YAHIA, 2009). A respiração é alta após a frutificação, diminuindo e mantida em baixas taxas até o amadurecimento. O início da produção de etileno desencadeia e coordena as mudanças que ocorrem no amadurecimento, incluindo mudanças na cor da polpa e casca, diminuição dos teores de clorofila com aumento dos carotenoides, diminuição da firmeza com aumento da suculência da polpa, conversão de amido em açúcares, aumento do conteúdo de sólidos solúveis totais, diminuição da acidez, aumento de voláteis característicos e aumento da produção de CO_2 e de etileno.

O conteúdo de ácido 1-aminociclopropeno-1-carboxílico (ACC), o precursor imediato de etileno, aumenta em diferentes tecidos (casca e mesocarpo) durante o amadurecimento, ao passo que ACC oxidase (ACO), que catalisa a conversão de ACC a etileno, e a produção de etileno diminuem (REDDY; SRIVASTAVA, 1999). A casca da manga tem as maiores taxas de produção de etileno e ACO e menores taxas de acumulação de ACC do que o mesocarpo no estádio verde-maduro.

Muitas mudanças metabólicas importantes ocorrem durante a maturação e o amadurecimento de mangas, sendo úteis como índices de qualidade e maturação (YAHIA; ORNELAS-PAZ; ARIZA, 2006). Mudanças no conteúdo de açúcares são muito importantes para atributos sensoriais em mangas, sendo o sabor e o aroma quase que inteiramente o balanço entre o conteúdo de açúcares e o de ácidos orgânicos, assim como o conteúdo de voláteis (YAHIA, 2011).

O aprimoramento da qualidade tem sido utilizado na determinação de propriedades críticas para a aceitação do sabor e do aroma em mangas, tendo sido realizadas algumas entrevistas com grupos de interesse para a determinação de atributos sensoriais importantes para a compra e o consumo de mangas (YAHIA, 2011). Sacarose e ácido cítrico são, respectivamente, o açúcar e o ácido predominante em mangas. Alguns fatores afetam o conteúdo e a taxa de açúcares e ácido em mangas, como, por exemplo, a cultivar, o estádio de maturação, os tratamentos pós-colheita e as condições de armazenamento. Matéria seca é uma parte do peso da amostra, obtida, normalmente, após a secagem do peso fresco e expressa em porcentagem. Na colheita, a matéria seca dos frutos é composta de amido, açúcares, ácidos orgânicos, minerais, pectinas e outros compostos.

O aumento dos açúcares solúveis é a principal mudança que ocorre no amadurecimento de mangas e é a mudança composicional mais importante relacionada ao sabor e ao aroma dos frutos, como, por exemplo, para a doçura. O conteúdo de amido aumenta durante o desenvolvimento do fruto e é quase completamente hidrolisado em açúcares mais simples durante o amadurecimento (ITO; SASAKI; YOSHIDA, 1997). O aumento no conteúdo de sacarose no amadurecimento é resultante da hidrólise do amido, por meio do aumento da atividade da enzima amilase. O amaciamento dos frutos e as mudanças na parede celular são notáveis e estão associados com o amadurecimento, estando envolvidos processos enzimáticos e não enzimáticos, além da atividade da enzima poligalacturonase (PG). Os fatores anteriormente citados, em associação, conduzem os consumidores a uma prefência por frutos maduros, sendo o sabor e o aroma atributos sensoriais de grande importância. Para que a preferência do consumidor e as características sensoriais sejam avaliadas, utilizam-se metodologias e técnicas da análise sensorial em alimentos.

2.3 Avaliação sensorial de alimentos

Avaliação sensorial de alimentos compreende técnicas para a medição acurada de resposta humana a alimentos e minimiza um possível efeito de polarização de padrões de identidade e outras informações que possam influenciar a percepção do consumidor. O isolamento de propriedades sensoriais faz-se possível, provendo importantes informações no desenvolvimento e características de produtos, para a ciência de alimentos e profissionais da área.

A análise sensorial tem sido definida como um método científico para medir, analisar e interpretar respostas a produtos percebidas por meio dos sentidos (STONE; SIDEL, 2004). Essa definição tem sido aceita e endossada por comitês de avaliação sensorial com várias organizações de profissionais, como a Associação Americana de Testes e Materiais e o Instituto de Tecnologistas de Alimentos.

Informação a respeito da qualidade dos produtos é um dos aspectos principais da biologia pós-colheita aplicada. Protocolos para a determinação da qualidade nas perspectivas instrumentais e fisiológicas estão bem estabelecidos, porém, é necessário que os trabalhos com pós-colheita tenham acesso a informações como gosto, sabor, aroma e textura dos produtos estudados (BROOKFIELD et al., 2011).

A análise sensorial de alimentos dá diretrizes para a preparação e o oferecimento de amostras em condições controladas de modo que condições externas são minimizadas. Por exemplo, pessoas em um teste sensorial são, normalmente, colocadas em cabines individuais e os julgamentos que fazem são pessoais e não refletem a opinião de pessoas próximas. Amostras são etiquetadas com números aleatórios para que os indivíduos não façam o julgamento com base no número da etiqueta, mas somente em suas experiências sensoriais. Outro exemplo seria como os produtos são apresentados em diferentes ordens para cada participante, com o objetivo de ajudar na medição e no contrabalanceamento e para evitar efeitos devido a sequências de apresentação. Procedimentos padrões podem ser estabelecidos para a amostra, visando à precisão e ao controle de variação indesejada (LAWLESS; HEYMANN, 2010).

Os métodos atualmente utilizados para avaliação sensorial de alimentos compreendem um conjunto de técnicas com registros pré-estabelecidos para uso na indústria e em pesquisas acadêmicas (LAWLESS; HEYMANN, 2010). O primeiro interesse do especialista em análise sensorial de alimentos é garantir que o método do teste seja eficiente para responder a questões a respeito do produto em teste. Por esta razão, testes são, usualmente, classificados de acordo com o seu primeiro propósito e seu uso mais comum. Três tipos de testes sensoriais são comumente utilizados, cada um com um objetivo diferente e utilizando participantes selecionados por critérios diferentes. Na Tabela 2 apresenta-se um resumo dos três tipos de testes utilizados em análise sensorial de alimentos. No presente trabalho utilizou-se o teste sensorial descritivo, pela análise descritiva quantitativa (ADQ) e também foi realizado um teste afetivo, que mediu a aceitação dos consumidores por meio de escala hedônica.

Tabela 2: Classificação de métodos de testes em avaliação sensorial de alimentos.

Classe	Questão de interesse	Tipo de teste	Características dos provadores
Discriminativo	É possível perceber a diferença entre os produtos em algum sentido?	Analítico	Selecionados pela aquidade sensorial, orientados para o método do teste, às vezes treinados.
Descritivo	Como os produtos diferem em características sensoriais específicas	Analítico	Selecionados por acuidade sensorial e motivação, treinados ou altamente treinados.
Afetivo	Quão bem os produtos são aceitos ou quais são os produtos preferidos	Hedônico	Selecionados para produtos, não-treinados.

Fonte: Lawless e Heymann (2010)

2.3.1 Teste descritivo - Análise descritiva quantitativa (ADQ)

Com a utilização do teste descritivo pela ADQ, é possível quantificar as intensidades de características sensoriais de um produto, percebidas por provadores treinados. Ela tem sido avaliada como a ferramenta mais informativa e compreensiva em avaliação sensorial, sendo aplicada na caracterização de uma grande variedade de produtos, em suas mudanças e desenvolvimento. A informação obtida pode ser relacionada com a aceitação do consumidor e medições instrumentais por meio de técnicas estatísticas, como regressão e correlação (LAWLESS; HEYMANN, 2010). É muito utilizada para traçar, de forma mais completa possível, o perfil sensorial dos atributos de aparência, odor, textura e sabor, pois identifica os atributos e os quantifica na ordem de ocorrência. Primeiramente, os atributos são decompostos pela equipe sensorial que busca os termos descritores, seus significados, materiais de referências adequados e a melhor seqüência de avaliação. O julgador descreve as similaridades e as diferenças entre pares de amostras e os termos gerados são listados por consenso, permanecendo os citados em maior número de vezes para compor a ficha.

Os dados obtidos são, normalmente, submetidos à análise de variância, podendo ser utilizados outros tratamentos estatísticos, de acordo com os objetivos do teste, como técnicas de análise multivariada. Diferenças entre tratamentos devem ser analisadas utilizando-se testes de comparação de médias, tais como de Tukey, Duncan ou Student-Newman-Keuls (SNK). A ADQ pode ser representada por gráfico aranha e por análise de componentes principais (ACP), em que a primeira sugere similaridades e diferenças entre as amostras e a segunda aponta para relações existentes entre elas, evidenciando o que mais as caracteriza. Recomenda-se que o número de julgadores selecionados seja entre 8 e 25 provadores treinados. O desempenho de cada julgador deve ser avaliado por testes com duas ou mais amostras diferentes, em pelos menos três repetições. O critério de seleção é para os julgadores que discriminam amostras com probabilidade (p) menor ou igual a 0,50, pela ANOVA (INSTITUTO ADOLFO LUTZ, 2008).

2.3.2 Teste afetivo – teste de aceitação por escala hedônica

O grau de aceitação de um produto pode ser quantificado por meio dos testes afetivos e pela utilização da escala hedônica. Por esse último, o consumidor/provador expressa o grau de gostar ou de desgostar de uma amostra, de forma globalizada ou em relação a um atributo específico. As escalas mais utilizadas são as de 7 e 9 pontos, que contêm os termos definidos situados, por exemplo, entre “gostei muitíssimo” e “desgostei muitíssimo”, contendo um ponto intermediário com o termo “nem gostei, nem desgostei”. É importante que as escalas tenham um número balanceado de categorias para gosto e desgosto. As amostras codificadas com algarismos de três dígitos e aleatorizadas são apresentadas ao julgador para avaliar o quanto gosta ou desgosta de cada uma delas por meio da escala previamente definida e sua preferência é obtida por inferência. Os dados coletados podem ser avaliados estatisticamente pela análise de variância e comparação das médias de pares de amostras pelo teste de Tukey. Recomenda-se que o número de julgadores seja entre 50 e 100 (INSTITUTO ADOLFO LUTZ, 2008).

2.4 Avaliação da qualidade de frutos por métodos não destrutivos

O desenvolvimento e uso de novas técnicas não destrutivas para a colheita de manga torna-se imprescindível para garantir a homogeneidade da qualidade dos frutos ofertados no mercado. A determinação precisa e não destrutiva do estádio de maturação de manga também é necessária na melhoria da eficiência das operações de colheita, visando à oferta de frutos de alta qualidade. Além da aplicabilidade comercial, a determinação precisa da maturação dos frutos é de grande importância para estudos científicos, uma vez que as pesquisas realizadas atualmente estão susceptíveis à alta variabilidade de maturidade e de qualidade das amostras utilizadas (BETEMPS; FACHINELLO; GALARÇA, 2011). Neste caso, métodos não destrutivos tornam-se imprescindíveis não somente para atender à demanda do consumidor por frutos mais homogêneos e com maior qualidade, mas também para aumentar a precisão e a repetibilidade dos resultados obtidos em pesquisa.

Existe uma grande diversidade de métodos não destrutivos utilizados para a determinação de parâmetros de qualidade em produtos agrícolas, como ressonância magnética, raios X, tomografia, colorimetria, fluorescência e espectroscopia de infravermelho próximo (JHA; MATSUOKA, 2000). Entre os métodos não destrutivos, estudos mostram que a espectroscopia de infravermelho próximo é o método mais apropriado para a determinação de parâmetros de qualidade em mangas, já que não sofre interferência da pigmentação da casca e do caroço presente nos frutos (SARANWONG; SORNSRIVICHAL; KAWANO, 2001; SUBEDI; WALSH; OWENS, 2007). Outra vantagem do uso de espectroscopia de infravermelho próximo é a rápida determinação de parâmetros de qualidade de forma não destrutiva, após a calibração e a validação do método para cada material genético e condições de cultivo (SUBEDI; WALSH; OWENS, 2007), sendo possível a avaliação individual dos frutos e o acompanhamento e/ou indicação da qualidade final dos mesmos.

A espectroscopia de infravermelho próximo tem sido utilizada em laboratórios e indústrias, e a análise do espectro de reflexão do infravermelho próximo permite a determinação não destrutiva de substâncias diversas, principalmente na quantificação do teor de matéria seca, amido, açúcares, ácido málico e clorofila em manga, os quais podem ser utilizados para uma precisa determinação do estádio de maturação (BETEMPS; FACHINELLO; GALARÇA, 2011; SARANWONG; SORNSRIVICHAI; KAWANO, 2004; SCHMILOVITCH, 2000; SUBEDI; WALSH; OWENS, 2007). Além do potencial para a determinação do estádio de maturação e a qualidade de frutos, a espectroscopia de infravermelho próximo também tem sido sugerida como uma técnica para predizer a qualidade de consumo e vida pós-colheita de mangas, no momento da colheita (SARANWONG; SORNSRIVICHAI; KAWANO, 2004; SUBEDI; WALSH; OWENS, 2007).

O espectômetro de mão (Modelo Nirvana-Analytical Spectrometer, Integrated Spectronics, Sydney, Australia) é utilizado para a medição do espectro em mangas intactas entre os comprimentos de onda de 400 nm e 1000 nm, com resolução de 3 mm e uma largura de banda ótica de 8 a 13 nm. O instrumento tem um computador de bordo acoplado ao sistema operacional Windows CE®, permitindo download dos dados de conteúdo de matéria seca dos frutos (Figura 1).

Figura 1: Equipamento com infravermelho próximo utilizado nas avaliações de conteúdo de matéria-seca em mangas durante o armazenamento.

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SEGUNDA PARTE- ARTIGOS

ARTIGO 1: QUALITY INDEXES AND CHANGES DURING RIPENING ON MANGO CULTIVARS

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Abstract

Although mango is widely produced and consumed around the world, consumers have experienced inconsistent quality due to inappropriate practices. Better physico-chemical characterization after harvest and identification of parameters to predict ripe and 'ready to eat' fruit quality is required to ensure higher and homogeneous fruit quality in the market. The objectives of this study were to characterize changes during ripening and to identify parameters that can be used as a final quality index of mango fruit. For postharvest changes, fruit of mango cultivars Ataulfo, Haden and Tommy Atkins were stored at 20°C and >85% of relative humidity for 12 days. Fruit analyses were accomplished every two days. The results show that the soluble solid content (SSC) and titratable acidity (TA) ratio (SSC:TA) increased during storage in all cultivars. For correlations between quality parameters and consumer acceptance on mature and ripe fruit, fruit from Ataulfo and Tommy Atkins cultivars were used and there is a very strong correlation between destructive DM in mature fruit and SSC when the same fruit is ripe (r = 0.98 and 0.90). Fruit with higher dry matter content had no effect on degree of liking in 'Ataulfo' mangoes, but increased the degree of liking in 'Tommy Atkins' mangoes from Mexico. The average DM of ripe Brazilian mangoes is lower than in ripe Mexican mangoes, which has negative effects on consumer acceptance. Fruit dry matter content can be precisely determined non-destructively with the near infrared spectrometer 'NIRvana'. The results indicate that dry matter is a stable parameter throughout fruit ripening process that can be used to precisely predict the SSC that affect final consumer quality of mango fruit.

Keywords: Consumer; *Mangifera indica* L.; postharvest; storage; dry matter

Resumo

Apesar da manga ser um fruto grandemente consumido e produzido em todo o mundo, consumidores têm se deparado com qualidade incosnsistente devido a práticas inapropriadas. Uma melhor caracterização físico-química após a colheita e identificação de parâmetros para predizer qualidade do fruto maduro e pronto para o consumo é requerida para garantir uma qualidade maior e mais homogênea no mercado. Os objetivos desse estudo foram caracterizar mudanças durante o amadurecimento e identificar parâmetros que podem ser utilizados como índice final de qualidade em mangas. Para mudanças pós-colheita, frutos das cultivares Ataulfo, Haden e Tommy Atknis foram armazenados a 20°C e umidade relativa >85% por 12 dias. Os resultados mostram que a taxa sólidos solúveis totais (SSC) e acidez titulável (TA) (SSC:TA) aumentou durante o armazenamento em todas as cultivares. Para correlações entre parâmetros de qualidade e aceitação de consumidores em frutos maturos e maduros, frutos das cultivares Ataulfo e Tommy Atkins foram utilizados e há uma correlação muito forte entre matéria seca avaliada por modo destrutivo (DM) em frutos maturos e teos de sólidos solúveis totais (SSC) quando o meso fruto está maduro (r=0,98 e 0,90). Maiores tores de matéria seca no frutos não influcenciou o grau de aceitação em mangas ‘Ataulfo’, mas aumentou o grau de aceitação em mangas ‘Tommy Atkins’, ambas provenientes do México. A média de matéria seca em mangasprovenientes do Brasil é menor que em mangas maduras provenientes do México. O conteúdo médio de matéria seca em mangas do Brasil é menor do que em mangas maduras provenientes do México, o que desencadeia um efeito negativo na aceitação do consumidor. Matéria se Ca dos frutos pode ser precisamente determinada não-destrutivamente pelo uso do infra vermelho próximo ‘NIRvana’. De acordo com os resultados, matéria seca é um parâmetro estável no processo de amadurecimento do fruto e pode ser usado para predizer o teor de sólidos solúveis que irá afetar a qualidade final do fruto para o consumidor.

Palavras-chave: consumidor, *Mangifera indica* L.; pós-colheita, armazenamento; matéria-seca

1. Introduction

Mango (*Mangifera indica* L.) is widely cultivated in many tropical and sub-tropical regions, being one of the most popular fruit consumed in the world. Commercial mango production is reported in more than 87 countries. Mango production takes place in Central and South America, Australia, South-east Asia, Hawaii, Egypt, Israel and South Africa, especially for export markets (Tharanathan et al., 2006). Its production has reached 30 million tons in 2010, representing the second most produced tropical fruit in the world, after banana (FAOSTAT, 2013). Mango has a short production season and storage life, making the fruit prices increase consistently after its growing season (Sivakumar et al., 2011).

There are many mango cultivars available in the market and some of them have strong aroma, intense peel coloration, delicious taste and high nutritional value (Thanaraj et al., 2009). Although mango consumption can provide a significant amount of bioactive compounds with antioxidant activity, consumers have been experiencing along the years inconsistent fruit quality due to variability in maturity at harvest and ripening conditions.

Several important metabolic changes occur during maturation and ripening of mangoes, and some of those are useful as maturity and quality indices (Yahia, 2005). Starch content increases during mango fruit development and it is almost completely hydrolyzed into simple sugars during ripening. (Yahia, 2011). The increase in soluble sugars is one of the major changes during fruit ripening that strongly affect mango flavor (Yahia, 2011). However, measuring the chemical properties to predict the final quality is invasive, and thus prohibits the use of the same sample to evaluate eating quality. Previous studies have shown that Near InfraRed (NIR) has the capability to evaluate soluble solids content (SSC) and dry matter (DM) in ripe mango fruit (Saranwong et al., 2001; 2003) and can be also used to measure harvest quality of hard green mango fruit nondestructively (Saranwong et al., 2004).

Variability in mango quality can be identified in the supply chain through the analysis of fruit taste, flavor, color, aroma, weight, size and shape, which can be influenced by pre and postharvest practices. Previous studies have shown that quality performance of mangoes depends largely on external and internal quality parameters (Kader, 2002).

In the market, appearance and freshness are the primary quality criteria for consumers. However, subsequent purchases depend on the satisfaction in texture and flavor (aroma and taste) quality of 'ready to eat' products (Beaulieu and Baldwin, 2002; Kader, 2002; Kays, 1999). Moreover, nutritional value and product safety are also taken into consumer consideration. All these crucial quality characteristics depend on both preharvest and postharvest factors, such as handling practices and storage conditions (Kader, 2002). Successful postharvest handling of mangoes requires knowledge of the postharvest physiology of the fruit and the appropriated handling practices to maintain high fruit quality to consumers (Yahia, 2005; Brecht and Yahia, 2009).

The objectives of this study were to characterize changes during ripening of 'Ataulfo, 'Haden' and 'Tommy Atkins' mangoes and to identify indexes that can be used to predict final consumer quality of mango 'Ataulfo' and 'Tommy Atkins' mango fruit.

2. Materials and methods

2.1. Plant Material

Mangoes cultivar Ataulfo, Haden and Tommy Atkins submitted to hot water treatment and in a mature stage were imported and obtained from a commercial wholesale in San Francisco, CA, US on June, 2012. The fruit were transported to the Postharvest Laboratory at University of California, Davis, CA, US. At the same day, fruit with external injury were eliminated and the mango boxes were kept in a storage room at 20°C and >85% of relative humidity (RH).

2.2. Fruit quality evaluation

The objective color of each fruit was measured at each evaluation time using a Minolta (model CR-400, Minolta, Ramsey, NY) colorimeter with an 8 mm light path aperture. The instrument was calibrated with a Minolta standard tile CR-400 (Y = 93.5, x = 0.3114, y = 0.3190). The mean of readings at four equidistant points (n = 4) around the equatorial axis was recorded and the lightness (L*), Chroma (color saturation; C*) and hue angle (H°) were automatically calculated. For each fruit, four measures of skin color and four measurements of flesh color were carried out and the average of the measurements per fruit was used to calculate the final average for each evaluation time.

Fruit flesh firmness was measured as resistance to penetration using a portable penetrometer (Effegi, Milan, Italy) with a 8 mm probe on opposite sides at the equator of each fruit after removal of peel (~2 mm thick) with a stainless steel vegetable peeler. Data were calculated as the mean of measurements from each fruit sample and expressed in Newtons (N).

Soluble solids concentration (SSC%) and titratable acidity (TA) were determined in juice samples extracted by squeezing, in two layers of cheese cloth, two longitudinal wedges cut from both sides of the fruit and pooled to form a composite sample. The juice SSC was measured with a temperature-compensated digital refractometer (PR 32 α, Atago, Tokyo, Japan) and the content of citric acid equivalents was determined with an automatic titrator (model TitraLab 850, Radiometer Analytical SAS, Lyon, France) connected to a sample changer (model SAC80, Radiometer Analytical SAS, Lyon, France), by tritating 4 mL of juice with 0.1 moL L^{-1} NaOH to endpoint pH 8.2. Initial pH in the juice was measured when the samples were placed on the automatic titrator.

Determination of dry matter through a destructive method: slices with 18 mm were cutted from the longitudinal part of each mango from all replicates, weighted, placed on the dehydrator (Dehydrator: Nesco/American Harvest Snackmaster® -Pro Food Dehydrator) and weighted again after 8 hours, 12 hours or when the final weights were constant. The dry weight was calculated based on the difference between the fresh and dry weight and the results were given in percentage.

Determination of dry matter through a non-destructive method: a handheld spectrometer (Model Nirvana-Analytical Spectrometer, Integrated Spectronics, Sydney, Australia) was used to measure the interactance spectrum of the intact mangoes between the wavelengths of 400 nm and 1000 nm at a data resolution of 3nm and an optical bandwidth ranging from 8 nm-13 nm. The instrument used a 0° illumination angle and 0° detection view angle configuration where the detector is placed in the center of the optical beam, causing a shadow on the fruit surface (Greensill and Walsh, 2000; Walsh et al, 2004). The interactance spectrum was then measured in the shadow cast on the fruit surface by the detector. The spectrophotometer was controlled by a built-in pocket-pc style computer running the Windows CE operating system. This design allowed the user to both download spectral data measurements for off-line analysis and model development and then to upload the developed statistical models for real-time. The results were given in percentage of dry matter.

For starch content, the estimation was determined spectrophotometrically. A 10 mL aliquot of distilled water and 50 µl of a thermostable α-amylase (Termamyl, activity 120 kNu/g; Novo Industri, A/S Copenhagen, Denmark) were added to each sample, mixed, and the tubes were then heated in boiling water bath for 90 min. After cooling, the tube contents were rinsed, and the buffer was added to the container with thorough mixing to give a final solution. About 1 mL from each sample was centrifuged in a 1.5 mL microcentrifuge tube at 8000× *g* for 2 min. A 200 µL aliquot of supernatant from each sample was added to a culture tube (16 **x** 125 mm), followed by 400 µ1sodium citrate buffer (pH 4.6), 350 µL distilled water and 50 µL myloglucosidase (Boehringer Mannheim 737160, 14 U/mg). The contents were mixed and then hydrolyzed by incubating at 60°C for 20 min. Starch concentration was calculated as milligrams per gram of fresh tissue and corrected for the appropriate dilutions and was also corrected for the amount of residual tissue subsampled for analysis and multiplied by 0.9; this factor accounted for the mass of glucose theoretically hydrolyzed from a unit mass of starch.

2.3. Respiration and ethylene production rates

Were measured by placing a single fruit into a sealed 3.8 L jar at 20ºC for 10–90 min, depending on the rate of gas production. Ethylene production was calculated by ethylene concentration in the gas phase of the jars, determined by withdrawing a 10 mL headspace gas sample from each jar and injecting it into a 2 mL fixed sample volume valve of a gas chromatograph (model Carle AGC-211, EG&G Chandler Engineering, Tulsa, OK, USA) equipped with two stainless steel columns (1.22 m and 0.305 m) packed with 8% NaCl on Alumina F-1 80/100 DV (EG&G Chandler Engineering, Tulsa, OK, USA) and a flame ionization detector. Nitrogen (N_2) was used as the carrier gas at a flow rate of 0.5 mL s^{-1} while O_2 and H_2 were used to create the flame of the detector at flow rates of 5 and 0.5 mL s^{-1}, respectively. Injector, oven and detector temperatures were 80◦C and the 7.4 ppm standard was used. Respiration rate was calculated by carbon dioxide concentration in the gas phase of the jars, determined by withdrawing a 10 mL headspace gas sample from each jar and injecting it into a PIR-2000R (Horiba Instruments Inc., Irvine, CA, USA). Nitrogen was used as the carrier gas at a flow rate of 0.33 mL.s^{-1}. Ethylene production was expressed as mg C_2H_4 Kg^{-1} h^{-1} and respiration rate as mg CO_2 Kg^{-1} h^{-1}. A standard of 0.25% CO_2 was used and volumes are relative to total pressure of 101 kPa and 20°C.

2.4. Consumer test

Consumers participated in the tests, based on availability and their response that they had no sensitivity or allergies to mangoes or similar food products and that they consume fresh mangoes. The experiment design (William´s design), the three digit code and presentation order for the consumer test were randomized using the Software Compusense 5 (Compusense, 1998) and one piece of mango of approximately 2 cm per fruit was evaluated by each consumer (Lawless and Heymann, 2010).

The samples were prepared in the postharvest lab in Wickson Hall at University of California, Davis, and were transported to the store taking into full consideration the sample sequence number so as to keep a track of the fruit characteristics and its consumer response. Later at the supermarket, the sample trays were prepared in the produce room out of sight from the testing area. Consumers rated their overall impression for each sample and the responses were recorded using a 9 point hedonic scale (degree of liking: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely). Consumer acceptance was measured as degree of liking (1–9) (Lawless and Heymann, 2010). The consumer was instructed to sip bottled water in between samples to cleanse the palate.

For the consumer response to different dry matter ranges in mango fruit, the dry matter content (DM) was measured on each previously labeled ripe fruit and the samples were presented to the consumers and correlated with their responses. Each consumer was presented in random order samples to define consumer quality for the two mango cultivars available in the market, "Ataulfo" and "Tommy Atkins"

2.5. Experiment design

Fruit were evaluated on every two days for the postharvest changes (until 12 days), ethylene and CO_2 (until 12 days for 'Ataulfo and until 18 days for 'Haden' and 'TommyAtkins'). For physico-chemical characteristics, 10 fruits per time of evaluation were used and for respiration and ethylene measurements, a single fruit were placed into a sealed 3.8 L jar at 20ºC.

For correlations on mango fruit on mature and ripe stages, the same fruit were used and were kept at 20°C during ripening. Measurements were carried out on mature and ripe stages for Ataulfo and Tommy Atkins cultivars.

Correlations between fruit destructive dry matter and consumer acceptance were carried out in ‘Ataulfo’ and ‘Tommy Atkins’ fruit on ripe stage. Fruit were kept in a 20°C storage room until ripe stage and at the day of the test, fruit with the same dry matter content range were put together to a ‘in store’ consumer test.

For correlations between non-destructive dry matter and soluble solids content, destructive dry matter and consumer acceptance, fruit were kept in a 20°C storage room until ripe stage and at the day of the test measurements were carried out, keeping track of the number of each fruit. ‘Ataulfo’ and ‘Tommy Atkins’ mango fruit from Mexico and Brazil were used due to cultivar availability in the market.

All fruit were kept in a storage room with temperature and humidity controlled automatically. Just mangoes were stored and only authorized personal were able to enter in the storage room. Statistical analyses were performed using SAS (version 9.0, Cary, NC, US). Correlations were carried out in R program for statistical computing (R).

3. Results and discussion

3.1. Changes during fruit ripening

According to our results, flesh firmness of ‘Ataulfo’, ‘Haden’ and ‘Tommy Atkins’ mangoes decreased 32.9, 88.4 and 94.9% from 0 to 12 days at

20°C, respectively (Figure 1). The highest firmness loss took place during the first two days of storage, representing more than 88% of firmness loss for 'Haden' and 'Tommy Atkins' mangoes (Figure 1). These results agree with other studies, showing that rate of fruit softening is higher at the beginning of ripening, decreasing thereafter (Sane et al., 2005).

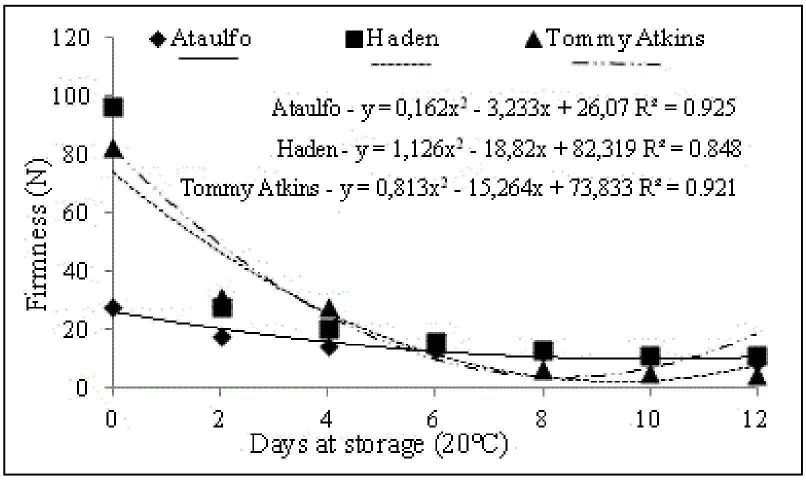

Figure 1. Firmness changes on mango cultivars during ripening for 12 days at 20°C.

The color analysis show that the Hue angle decreases in skin tissue during storage, going from green (119.31°, 106.0°) to orange (82.10°, 69.7°) in 'Haden' and 'Tommy Atkins' and the Hue angle in flesh tissue also decreases, going from yellow (85.6, 86.7, 94.7°) to orange (76.1, 84.5, 89.6°) for the three cultivars, respectively (Figure 2). The Hue angles in skin tissue of 'Ataulfo' mangoes indicate changes from yellow to yellow/orange. Chroma analysis shows that skin and flesh tissues increased the intensity of orange color during storage at 20°C in all cultivars (Figure 3). The lightness of skin (Figure 2) and flesh color (Figure 3) decreased in 'Ataulfo' and did not change in 'Haden' mangoes, whereas lightness of flesh color in ‘Tommy Atkins’ mangos decreased during storage (Figure 3). Climacteric fruit, such as mangoes, are known to change color during ripening mostly due to chlorophyll degradation and carotenoid synthesis (Tadmor et al., 2010).

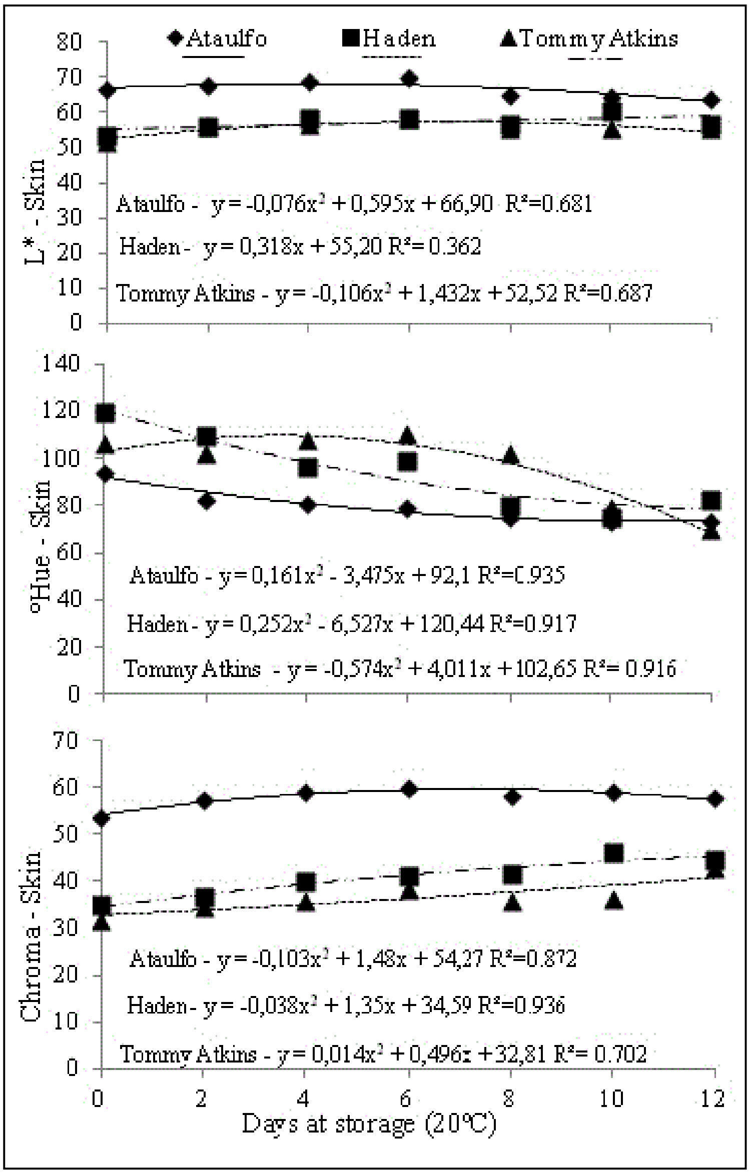

Figure 2. Skin color evaluations on mango cultivars during ripening for 12 days at 20°C.

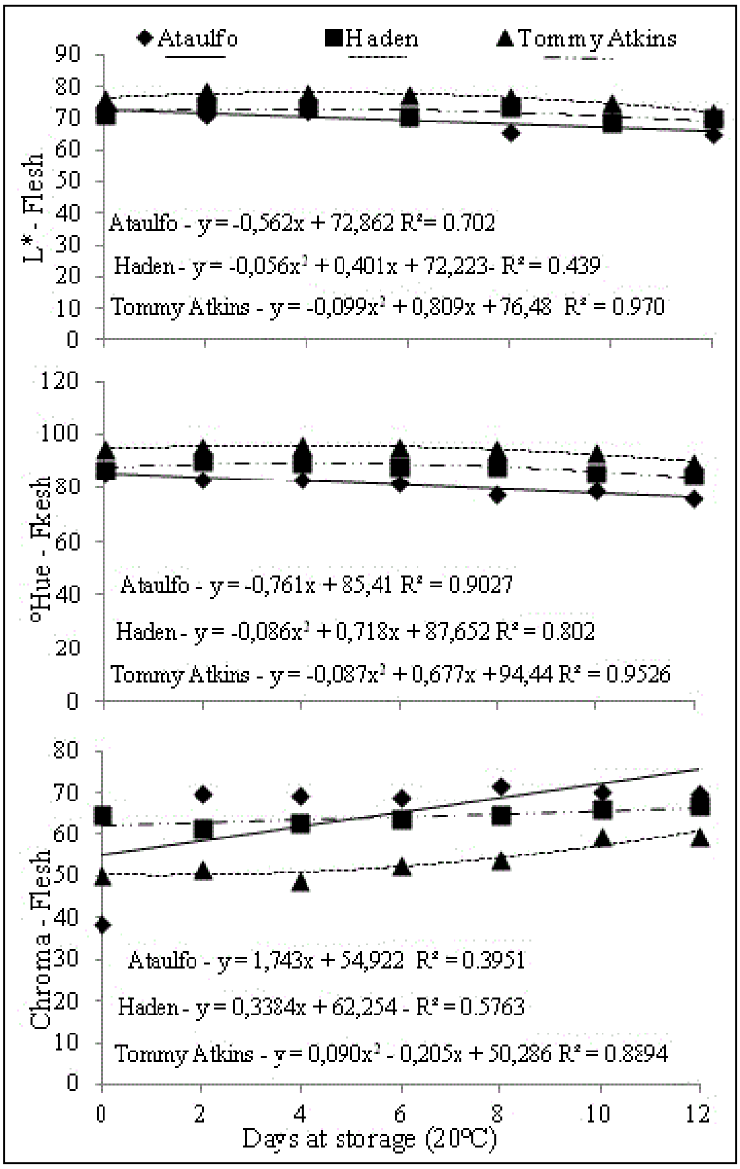

Figure 3. Flesh color evaluations on mango cultivars during ripening for 12 days at 20°C.

The soluble solids content increased from 10.30%, 12.7% and 16.9% at 0 days of storage to 12.14%, 13.6% and 20.3% at 12 days of storage in ‘Ataulfo’, ‘Haden’ and ‘Tommy Atkins’ mangoes, respectively (Figure 4). The citric acid content (acidity) decreased 91.14% in ‘Ataulfo’, 77.89% in ‘Haden’ and 83.58% in ‘Tommy Atkins’ mangoes, from the beginning to the end of storage period (Figure 4). Accordingly other studies have also shown that citric acid content decreases during mango fruit ripening (Padda et al., 2011; Othnan and Mbogo, 2009). The decline in acidity could be due to the fact that citric acid is rapidly oxidized in the citric acid cycle during ripening to produce the energy required for metabolic changes that take place during ripening (Aina, 1980).

In all cultivars the soluble solid content (SSC) and titratable acidity (TA) ratio (SSC:TA) increased during storage and the highest SSC:TA ratio increase occurred in ‘Ataulfo’ mangoes, starting as 8.93 at 0 days of storage and reaching 115.92 at 12 days of storage at 20 ºC. This increase in SSC:TA ratio in ‘Ataulfo’ mangoes was due to the most prominent increase in soluble solids and decrease in acidity observed during fruit ripening, compared to the other cultivars. High SSC:TA ratio have been reported to improve fruit flavor, increasing consumer acceptance and marketability of the fruit (Rodriguez-Pleguezuelo et al., 2012).

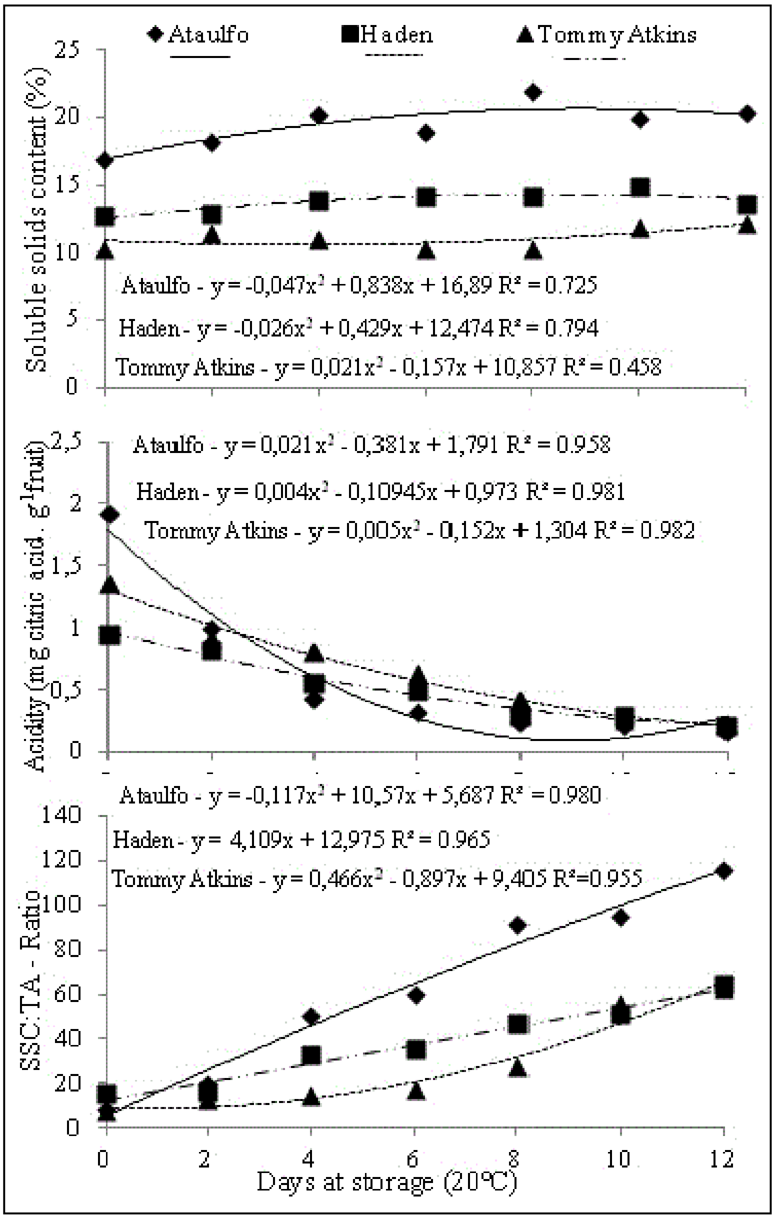

Figure 4. Soluble solids content (SSC), acidity (TA) and SSC:TA ratio for mango cultivars during ripening for 12 days at 20°C.

The juice pH increased during fruit ripening in all cultivars (Figure 5). Starch content decreased 55.8, 57.0 and 34.6% in ‘Ataulfo’, ‘Haden’ and ‘Tommy Atkins’ mangoes during ripening for 12 days at 20 ºC, respectively (Figure 5). The highest decrease in starch content were observed in ‘Haden’, compared to ‘Ataulfo’ and ‘Tommy Atkins’ mangoes (Figure 5). Studies have suggested that even when starch content at the beginning of ripening is less than 1%, it is sufficient to provide the carbon required for sugar synthesis (Castrillo and Kruger, 1992; Hubbard et al., 1991).

The dry matter content measured by a destructive method was constant during 12 days of storage at 20°C (Figure 5), suggesting that the observed changes in fruit metabolism related to changes in acidity, total soluble solids and starch contents were not enough to affect fruit dry matter content.

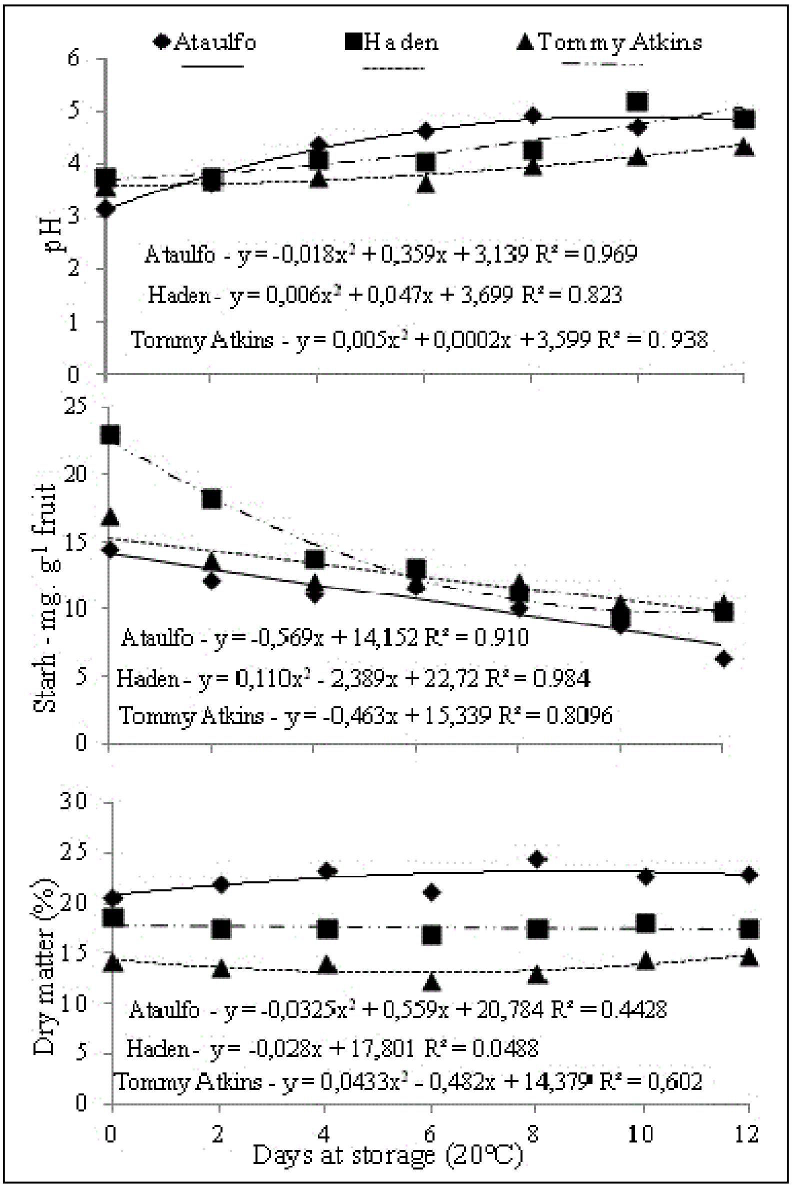

Figure 5. pH, starch content and dry matter on mango cultivars during ripening for 12 days at 20°C.

The pattern of respiration and ethylene production of ‘Haden’ and ‘Tommy Atkins’ mangoes showed an increase in CO_2 production at six days of storage, followed by an increase in ethylene synthesis, characterizing the climacteric burst in respiration and ethylene production during ripening (Figure 2). ‘Ataulfo’ mangoes showed higher ethylene (0.77 to 1.2 mg C_2H_4 kg^{-1} h-^{1}) and CO_2 production (251.0 to 160.0 mg CO_2 kg^{-1} h-^{1}) than the other cultivars (Figure 6). These differences in respiration and ethylene production among cultivars are due to the fact that fruit metabolism is genetically regulated (Krishnamurthy and Subramanyam, 1970).

After 12 days of storage, CO_2 production decreased and ethylene production increased (Figure 6), which may represent the beginning of fruit senescence.

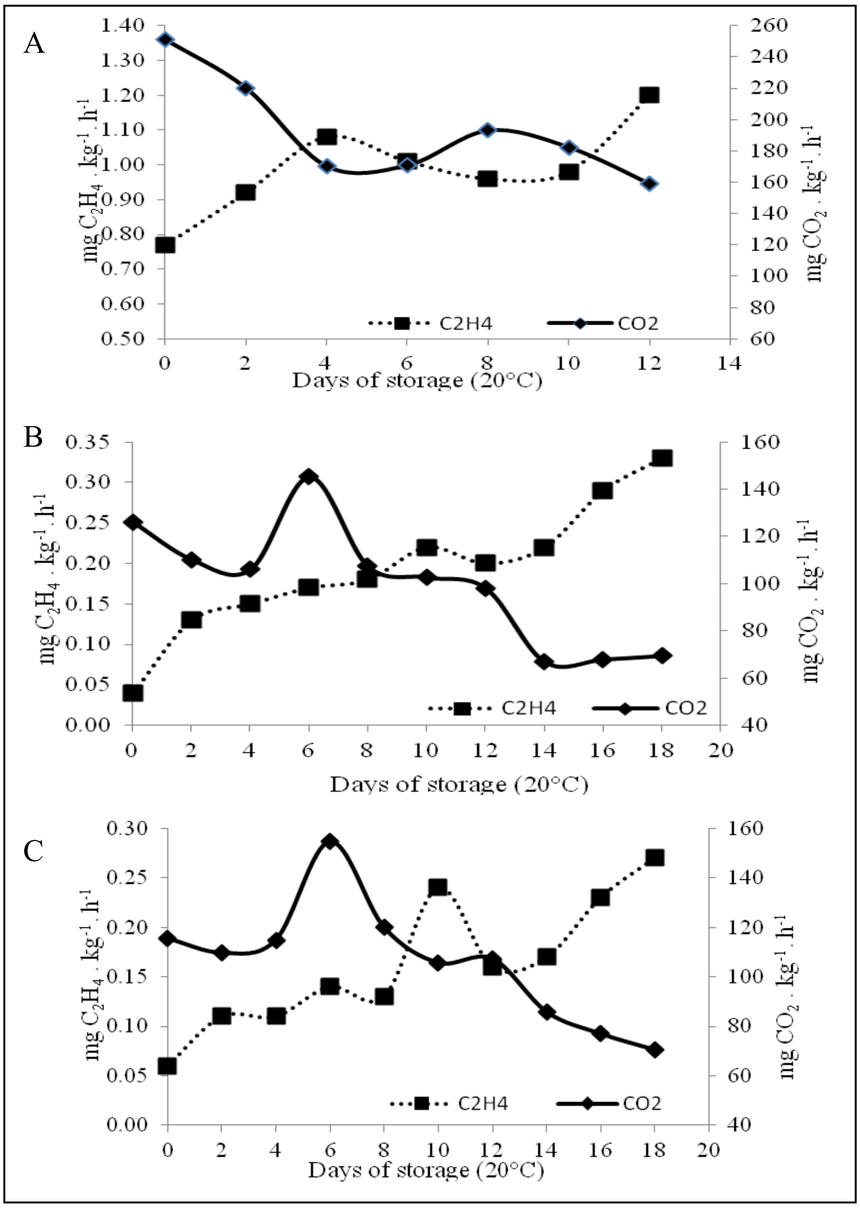

Figure 6- Respiration and ethylene production during storage of ‘Ataulfo’ (A), ‘Haden’ (B) and ‘Tommy Atkins’ (C) mangoes at 20°C.

3.2. Correlation between fruit destructive dry matter (DM) and soluble solids content (SSC) at mature and ripe stages

Mango fruit quality has been commercially determined based on external characteristics (Nguyen et al., 2004; Léchaudel and Joas, 2007). However, visual parameters are not precise and may result in misleading characterization and prediction of fruit quality and may not have a direct impact on the eating quality (Saranwong et al., 2004). Correlation analysis has been widely used to estimate and predict quality parameters in fruit. It has been proposed that significant correlations (P-values ≤ 0.05) between two parameters are strong when the correlation coefficient (r) ranges from 0.69 and 0.89 and are very strong when the 'r' is higher than 0.9 (Shimakura and Ribeiro Jr, 2005).

Our results show correlation coefficients between soluble solids content (SSC) on fruit at mature stage and SSC at ripe stage, dry matter (DM) content at fruit on mature stage and dry matter at ripe stage, as well as between dry matter content at mature stage and SSC at ripe stage ranging from strong (0.70) to very strong (0.98) for 'Ataulfo' and 'Tommy Atkins' mangoes (Table 1). The results show a very strong correlation between mature DM and ripe SSC ($r = 0.98$ and 0.90), as well as strong correlations between Mature SSC x Ripe SSC ($r = 0.75$ and 0.85) for both mango cultivars ('Ataulfo' and 'Tommy Atkins', respectively) (Table 1). Measurements were carried out on mature and ripe stages and the correlation coefficients and P-value for the correlation analysis were obtained for the same fruit (kept in a storage room at 20°C during ripening) at the beginning and the end of storage time (Table 1).

The correlation analysis indicate that dry matter content in mature mangoes is more suitable than soluble solid content on mature fruit to predict 'ready to eat' fruit quality, using ripe soluble solid as a quality index. In addition, the dry matter content shows little changes during ripening compared to soluble solids content (Figure 5 and Figure 4), which also makes the dry matter an appropriated parameter to predict SSC and final consumption quality of the fruit. The observed change in soluble solids content during ripening is a potential limitation for its use to predict final fruit quality.

The possibility to predict SSC in ready to eat mango based on its dry matter content at earlier stages of growth and development will help growers to determine market and price of their fruit at harvest. Retail stores will be able to determine fruit postharvest life and ensure the ripe and ready to eat fruit quality to consumers, stimulating mango consumption and commercialization.

Table 1. Correlation coefficient and P-value for 'Ataulfo' and 'Tommy Atkins' mangoes on mature and ripe stages. Measurements were carried out in the same fruit. n=18

Correlation	Correlation Coefficient (r)	P-value (P)
	'Ataulfo'	
Mature SSC x Ripe SSC	0.75	0.0019
Mature DM x Ripe DM	0.98	0.0000018
Mature DM x Ripe SSC	0.98	0.0000015
	'Tommy Atkins'	
Mature SSC x Ripe SSC	0.85	0.007
Mature DM x Ripe DM	0.70	0.054
Mature DM x Ripe SSC	0.90	0.002

3.3. Fruit destructive dry matter (DM) and consumer acceptance

The degree of liking and consumer acceptance of mangoes from Mexico with different dry matter ranges are presented on Table 2. According to our data obtained for 'Ataulfo' mangoes, the differences in dry matter content evaluated were not sufficient to affect the degree of liking, as well as the percentage of consumer acceptance and the percentage of consumers that neither like or dislike the fruit (Table 2). Fruit with higher dry matter content increase the percentage of consumers that dislike the fruit of 'Ataulfo' mangoes (Table 2). The data obtained for 'Tommy Atkins' mangoes from Mexico show that increasing fruit dry matter content increased the degree of liking and consumer acceptance (Table 2). Increasing dry matter content of 'Tommy Atkins' mangoes decrease both the percentage of consumer that neither like or dislike and the percentage of people that dislike the fruit (Table 2). Fruit with DM range from 17.0-22.0%, regardless the cultivar evaluated, show similar acceptance.

Table 2. Degree of liking and percentage consumer acceptance of 'Ataulfo' and 'Tommy Atkins' mangos from Mexico by American consumers at different levels of Dry Matter (DM).

Quality Attributes	n	Degree of Liking (1-9)[1]	Acceptance (%)	Neither Like nor Dislike (%)	Dislike (%)
'Ataulfo'					
DM 16.9-20.0	90	7.0a*	82.2	10.0	7.8
DM 20.1-22.0	114	6.9 a	84.2	6.1	9.6
DM 22.0-25.3	60	6.5 a	76.7	8.3	15.0
HSD		0.63			
p- value		0.21			
'Tommy Atkins'					
DM 11.6-14.5	126	5.8 c	64.3	11.9	23.8
DM 14.6-17.0	126	6.4 b	73.8	7.9	18.3
DM 17.1-21.8	108	7.1 a	84.3	3.7	12.0
HSD		0.56			
p- value		8.01×10^{-8}			

[1] Degree of liking: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely. * Same letters within the same column indicate no significant difference between means according to Tukey Test (5%).

Studies have shown that ripe mango fruit would have excellent eating quality and high SSC if the fruit contained sufficient amounts of DM and starch at harvest date, and the SSC of ripe mango fruit could be precisely predicted from the DM and starch measured nondestructively at harvest (Saranwong et al., 2004). Since dry matter is correlated to degree of acceptance, prediction of dry matter on ripe fruit and SSC based on dry matter at harvest can be used as an approach to determine final consumer quality. This approach will held determining the best market for the fruit based on consumer requirements.

The data obtained for 'Ataulfo' and 'Tommy Atkins' mangos produced in Brazil show that increasing DM content tends to increase the degree of liking as well as the percentage of consumer acceptance (Table 3).

Table 3. Degree of liking and percentage of consumer acceptance of Brazilian ‘Ataulfo’ and ‘Tommy Atkins’ mangos by American consumers at different levels of Dry Matter (DM).

Quality Attributes	n	Degree of Liking (1-9) [1]	Acceptance (%)	Neither Like nor Dislike (%)	Dislike (%)
		‘Ataulfo’			
DM 14.6-16.4	101	5.9 b*	65.3	9.9	24.8
DM 16.5-17.5	143	6.7 a	79.0	8.4	12.6
DM 17.6-19.3	114	6.9 a	82.5	8.8	8.8
LSD		0.54			
p- value		8.10^{-4}			
		‘Tommy Atkins’			
DM 10.1-11.5	118	4.7 b	38.1	16.9	44.9
DM 11.6-12.5	125	5.2 b	51.2	11.2	37.6
DM 12.5-14.0	114	5.4 a	56.1	11.4	32.5
LSD		0.57			
p- value		0.01			

[1] Degree of liking: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely. * Same letters within the same column indicate no significant difference between means according to Tukey Test (5%).

Fruit of both cultivars with the lowest DM content showed the highest percentage of people that neither like nor dislike the fruit (Table 3). The percentage of people that dislike the fruit decreased by increasing DM content (Table 3). Dry matter content increases in fruit and vegetables during growth and development and is mostly represented by carbohydrates such as starch and cell wall polysacharides (Akanbi et al., 2010; García-Luis et al., 2002). Breakdown of starch and cell wall polysacharides during ripening increases sugar content and sweetness of the fruit (Gomez et. al., 2002; Bernardes-Silva et al., 2003). Accordingly, our results show that DM content at harvest is highly correlated to ripe SSC. Therefore, high DM content at harvest results in higher sugar content, increasing the degree of liking and consumer acceptance of mango fruit at the ripe stage. 'Ataulfo' mangoes produced in Mexico and in Brazil with DM contents higher than 16.9 and 16.5%, respectively, showed no diference in the degree of linking, indicating that higher DM contents have no effect on consumer perception for this cultivar.

The average DM content in 'Ataulfo' mangoes produced in Mexico and Brazil were 21.1% and 16.9%, respectively. The average DM content in 'Tommy Atkins' mangoes produced in Mexico and Brazil were 16.7% and 12.0%, respectively. These results show that the average DM of Brazilian mangoes is lower than Mexican mangoes, which has negative effects on consumer acceptance. Lower DM content of Brazilian mangoes is possibly the result of early harvest accomplished to extend the postharvest life required for shiping and comercialization in the U.S., compared to mangos produced in Mexico. Therefore, new tecnologies have to be used to extrend the postharvest life of Brazilian mangoes, allowing later harvest and higher carbohydrate accumulation in the fruit. This will improve the eating quality and incentivate the comsumption of Brazilian mango in the U.S..

3.4. Correlations between non-destructive dry matter and soluble solids content, destructive dry matter and consumer acceptance on ripe and ready to eat fruit

The results showed that dry matter of mature fruit could be used to predict SSC in ripe and ready to eat fruit. The use of Near Infrared technology has been proposed as an approach to determine quality indexes in fruit tissue non-destructively (Schmilovitch et al., 2000; Saranwong et al., 2003, 2004). Therefore, this technology allows following changes in fruit quality during ripening and predicting the final consumer quality individual fruit during ripening.

The correlation analysis, accomplished with ripe and ready to eat fruit, showed that the dry matter determined non-destructively with Near InfraRed technology (NIRvana) were positive correlated with ripe soluble solids content (SSC), dry matter (DM) determined destructively and consumer acceptance (Liking) of 'Ataulfo' and 'Tommy Atkins' mangoes (Table 4).

The non-destructive dry matter measurements showed a very strong correlation with SSC on 'Ataulfo' mangoes and a strong correlation on 'Tommy Atkins' mangoes (Table 4).

Table 4. Correlations for destructive Dry Matter (DM), non-destructive dry matter -NIRvana (DM), soluble solids content (SSC) and consumer acceptance (Liking) of ripe ' Ataulfo' (n=60) and 'Tommy Atkins' (n=50) mangoes.

Correlation	Correlation Coefficient (r)	P-value (P)
	'Ataulfo'	
NIRvana (DM) x SSC	0.91	0.000
NIRvana (DM) x DM	0.59	$5.52\ e^{-7}$
NIRvana (DM) x Liking	0.35	0.006
	'Tommy Atkins'	
NIRvana (DM) x SSC	0.78	$3.02\ e^{-11}$
NIRvana (DM) x DM	0.63	$1.14\ e^{-6}$
NIRvana (DM) x Liking	0.30	0.033

The high precision of the non-destructive dry matter measurements and the high correlation between dry matter and SSC can be combined to predict the postharvest life and changes in consumer quality of a single fruit during ripening. Non-destructive and destructive measurements of dry matter are correlated (r=0.59 and r=0.63) for mangoes from cultivar Ataulfo and Tommy Atkins, respectively (Table 4).

For 'Ataulfo' and 'Tommy Atkins' mangoes, the highest correlation coefficients were observed between the non-destructive dry matter measurements and soluble solids content (SSC) (r=0.91, P-value=0.000 and r=0.78, P-value=3.02e^{-11}, respectively). These results show that even in ripe and ready to eat fruit the dry matter content is a good indicative of SSC. Other studies have shown that ripe mango fruit would have excellent eating quality and high SSC if the fruit contained sufficient amounts of dry matter (DM) and starch at harvest date, and the SSC of ripe mango fruit could be precisely predicted from the DM and starch measured non-destructively at harvest (Saranwong et al., 2004).

In our study, dry matter determined non-destructively was positively correlated with the consumer acceptance - Liking (r = 0.30 and 0.35) (Table 4). The low correlation coefficient values are possibly due to the fact that fruit sensory quality is not only determined by a single parameter such as SSC, but instead by the combined effect of wide range of parameters that determine each characteristic fruit flavor (Sun, 2012). Therefore, precise determination of final consumer acceptance will require estimation and/or prediction of a wider range of quality parameters non-destructively.

4.Conclusion

Dry matter (DM) content is stable during ripening of mango cultivars. There is a very strong correlation between dry matter on mature fruit and soluble solids content on ripe fruit.

For American consumers, the increase in DM content had no effect on degree of liking in ‘Ataulfo’ mangoes, but increased the degree of liking in ‘Tommy Atkins’ mangoes from Mexico. An increase in DM content increased the degree of liking and the percentage of consumer acceptance for ‘Ataulfo’ and ‘Tommy Atkins’ mangoes from Brazil.

Dry matter is stable during ripening and is highly correlated to degree of acceptance and the prediction of dry matter and SSC on ripe fruit based on dry matter and at harvest can be used as an approach to determine final consumer quality. This approach will held determining the best market for the fruit based on consumer requirements.

Fruit dry matter content can be precisely determined non-destructively with the near infrared spectrometer ‘NIRvana’ and the content can be used to monitor and as an index of ‘ready to eat’ quality of a single mango fruit after harvest.

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ARTIGO 2: SENSORY DESCIPTION AND IDEAL POINT OF CONSUMPTION ON MANGO CULTIVARS DURING RIPENING

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Abstract

Consumers determine fruit quality based on sensory attributes for each genotype and consumer preferences. The aim of this study was to subject fruit of mango cultivars Ataulfo, Haden and Tommy Atkins with three levels of flesh firmness to postharvest and descriptive sensory analyses. All fruit were kept at 20ºC and >85% of relative humidity to allow ripening. Fruit of each cultivar were evaluated with three level of flesh firmness - 'Ataulfo' (high = 32.3, medium = 20.6, low = 7.8 N), 'Haden' (high = 42.1, medium = 20.6, low = 8.8 N) and 'Tommy Atkins' (high = 13.8, medium = 9.3, low = 5.8 N). According to our results, softening of 'Ataulfo' mangoes was followed by an increase in Tropical Fruit and Sweet Peach Aromas, decrease in Fermented Aroma, increase in Juiciness, decrease in Fibrousness and Chewiness, increase in Sweet and Coconut Taste and decrease in Sour Taste. Softening of 'Haden' mangoes was followed by an increase in Tropical Fruit and Peach Sweet Aromas, decrease in Chewiness, increase in Sweet and Coconut Tastes and decrease in Sour and Bitter Tastes. Softening of 'Tommy Atkins' mangoes was followed by reduction in Chewiness, sensory firmness and Sour Taste and increase in Sweet Aroma. Softening of all cultivars were followed by a decrease in Sour Taste and citric acid content, as well as increase in total soluble solid (TSS):Titratable acid (TA) ratio and loss of skin green color and increase in flesh yellow/orange color. The results indicate that fruit softening is followed by an increase in desirable attributes to improve eating quality. The final changes in quality attributes are genetically controlled and specific for each genotype. 'Ataulfo' and 'Haden' mangoes showed better improvements in attributes related to fruit eating quality during softening.

Keywords: *Mangifera indica* L; consumer; descriptive analysis; firmness; ripening.

Resumo

Consumidores determinam a qualidade dos frutos baseados em atributos sensoriais para cada genótipo e de acordo com suas preferências. O objetivo desse estudo foi avaliar carcterísticas pós-colheita e sensoriais de mangas das cultivares Ataulfo, Haden e Tommy Atkins em três níveis de firmeza da polpa. Frutos foram mantidos à 20°C e UR>85% para permitir o amadurecimento. Frutos de cada cultivar foram avaliados em três subgrupos, de acordo com o grau de firmeza da polpa - 'Ataulfo' (alta = 32,3, média= 20,6, baixa= 7,8 N), 'Haden' (alta= 42,1, média= 20,6, baixa= 8,8 N) e 'Tommy Atkins' (alta = 13,8, média= 9,3, baixa= 5,8 N). De acordo com os resultados, diminuição da firmeza em mangas 'Ataulfo' foi seguida de aumento de Aroma de Fruto Tropical e Pêssego Doce, Suculência, Gosto Doce e Gosto de Coco, com decréscimo nos atributos Fibrosidade, Mastigabilidade e Gosto Amargo. Com o decréscimo da firmeza da polpa em mangas 'Haden', houve um aumento de Aroma Tropical e de Pêssego Doce, com diminuição do Gosto Amargo, Gosto Azedo e Mastigabilidade. Diminuição da firmeza da polpa em mangas 'Tommy Atkins' foi seguida por uma redução na Mastigabilidade, Firmeza sensorial e Gosto Amargo e aumento no Gosto Doce. Em todas as cultivares, frutos menos firmes foram caracterizados por menor Gosto Amargo e menor conteúdo de ácido cítrico, assim como maior teor de sólidos solúveis e taxa SSC:TA, menor coloração verde na casca e maior coloração alaranjada da polpa. Resultados indicam que a perda de firmeza nos frutos é seguido por um aumento de atributos sensoriais desejáveis que aumentam a qualidade do fruto. Mudanças finais em atributos de qualidade são geneticamente controladas e específicas para cada genótipo. Mangas 'Ataulfo' e 'Haden' apresentaram maiores melhorias em atributos relacionados à qualidade de consumo do fruto durante o amadurecimento.

Palavras-chave: *Mangifera indica* L; consumidor; análise descritiva; firmeza;

1. Introduction

Mango (*Mangifera indica* L.) is widely found and cultivated in many tropical and sub-tropical regions, being one of the most popular fruit consumed in the world. Commercial mango production is reported in more than 87 countries. Mango production takes place in Central and South America, Australia, South-east Asia, Hawaii, Egypt, Israel and South Africa, especially for export markets (Tharanathan et al., 2006). Its production has reached 30 million tons in 2010 (FAO, 2010), representing the second most produced tropical fruit in the world, after banana. Mango has a short production season and storage postharvest life, consequently fruit prices after seasonal peak can become very high (Sivakumar et al., 2011).

There are many mango cultivars available in the market and some of them have strong aroma, intense peel coloration, delicious taste and high nutritional value (Thanaraj et. al., 2009). Mango consumption can provide significant amounts of bioactive compounds with antioxidant activity and mango flesh can be green, yellow or orange, depending upon the cultivar and stage of ripeness. Mango are climacteric fruit and are often harvested when hard and mature, but not ripe. The stage of maturity at harvest is a very important factor. If the fruit is harvest immature, it will not ripen properly and will not attain characteristic color and flavor. (Suwonsichon et al., 2012). At the time of purchase, appearance and freshness are the primary quality criteria for consumers. However, subsequent purchases depend on the satisfaction in texture and flavor (aroma and taste) quality of ready to eat products (Beaulieu and Baldwin, 2002; Kader, 2002; Kays, 1999).

The enormous number of cultivars available deserves studies in order to understand how the sensory differences among the fruit of those cultivars at different ripeness stages might affect the marketability or export potential of a specific cultivar (Suwonsuchon et al, 2012).

One of the main approaches generally used to assess the product sensory quality is the descriptive analysis (DA), a sophisticated tool in sensory analyses that allow the complete sensory description of the product, providing detailed sensory profiles of products and/or product categories. (Lawless and Heymann, 2010).

Despite the numerous studies related to the effect of initial maturity and ripeness stages on the quality of mangos, the effect of ripeness stage on the sensory quality of mangos has not been well established. In addition little is known about the ending point of fruit consumption quality, when the fruit start losing the required consumer quality.

The aim of this study was to evaluate fruit of three mango cultivars in three firmness levels to have the sensory description of the material during ripening.

2. Material and methods

2.1 Samples:

Mango cultivars Ataulfo, Haden and Tommy Atkins from Mexico were obtained from a commercial wholesale in San Francisco, CA, US on June, 2012. The fruits were transported to the Postharvest Laboratory at the University of

California, Davis, CA, US. At the same day, fruits with external injury were eliminated and the boxes were kept at 20◦C and >85% of relative humidity (RH) to allow ripening. Fruit of each cultivar were segregated and evaluated on three ripening stages, determined based on fruit flesh firmness. The descriptive analysis was accomplished for each cultivar at the three levels of flesh firmness. The experiment followed a completely randomized design with 12 fruit per firmness level per cultivar (36 fruits per cultivar). Fruit used were ripe and ready to eat, with three ranges of firmness per cultivar, according to the characteristics of each cultivar

2.2 Postharvest characteristics during ripening:

Skin and flesh color were measured at each ripening stage using a Minolta (model CR-400, Minolta, Ramsey, NY) colorimeter with an 8 mm light path aperture. The instrument was calibrated with a Minolta standard tile CR-400 (Y = 93.5, x = 0.3114, y = 0.3190). The mean of readings at four equidistant points (n = 4) around the equatorial axis was recorded and the lightness (L*), chroma (color saturation; C*) and hue angle (H◦) were automatically calculated. For each fruit, four measures of skin and four measurements of flesh were carried out and the average of the measurements per fruit was used to calculate the final average per ripening stage.

Fruit flesh firmness was measured as resistance to penetration using a portable penetrometer (Effegi, Milan, Italy) with a 8 mm probe on opposite sides at the equator of each fruit after removal of skin (~2mm thick) with a stainless steel vegetable peeler. Data were calculated as the mean of measurements from a fruit sample and expressed in Newtons (N).

Juice samples were extracted by squeezing, with two layers of cheese cloth, two longitudinal wedges cut from both sides of the fruit and pooled to form a composite sample. The juice soluble solids content (SSC) was measured with a temperature-compensated digital refractometer PR 32 α (Atago, Tokyo, Japan). The titrable acidity (TA) was determined as the percentage of citric acid equivalents in juice samples. The TA was measured with an automatic titrator model TitraLab 850 (Radiometer Analytical SAS, Lyon, France) connected to an autosampler model SAC80 (Radiometer Analytical SAS, Lyon, France), by titrating 4mL of juice with 0.1 moL L^{-1} NaOH to endpoint pH 8.2. Initial pH in the juice was measured when the samples were placed on the automatic titrator.

Dry matter content was determined in 18 mm slices cut from the longitudinal part of each mango, weighted and placed on the dehydrator Nesco-Pro Food Dehydrator (American Harvest Snackmaster®, Two Rivers, WI, US) and weighted again when the final weight was constant. The dry weight was calculated with the difference between the fresh and dry weight and the results were given in percentage.

The mangos were non-destructively analyzed with a DA meter, which is a portable Vis/NIR instrument (Sinteleia, Bologna, Italy). By means of absorbency properties, it measures the chlorophyll content that can be used as an index of a fruit ripening state.

2.3 - Sensory descriptive analysis

The mango cultivars (Ataulfo, Haden and Tommy Atkins) were kept at 20°C until segregation based on flesh firmness and the descriptive analysis tests were conducted in the Sensory Lab at Wickson Hall, Department of Plant Sciences, University of California, Davis, US. The sensory room was prepared for the sensory test with absence of noise, different odors and other products. The fruit preparation was accomplished in another room.

For the sensory evaluation, 21 panelists were trained and the attributes, definitions and references used are presented in the following table.

Table 1: Attributes, definitions and references for 14 characteristics evaluated on the sensory descriptive analysis:

Attributes	Definitions	Reference, intensity, preparation
	Aroma	
Tropical fruit (coconut)	The intensity of tropical fruits like, papaya, and coconut, ranging from weak to strong tropical fruit aroma	Kern's nectar 0.5 ml, Mango, added coconut flakes, unsweetened, Bob's red mill – a pinch.
Peach aroma	The intensity of peach aroma, and sweet aromas, ranging from weak to strong.	Kern's mango nectar, 0.5 ml, added one cut piece of peach from a can Del Monte Diced peaches.
Citrus fruit (Sour, acidic)	The intensity of citrus fruits like orange, lime and lemon, ranging from weak to strong citrus aroma	Kern's mango nectar, mixed 50% with Newman's virgin lemonade, 200 ml, added 15-30 ml squeezed lemon.
Green (cucumber)	The intensity of cucumber and cucurbit aromas, ranging from weak to strong green aroma	Kern's mango nectar, 0.5 ml, added half a slice (0.5 cm) of English cucumber, cut in two.
Green (Pine)	The intensity of the smell of pine needles, ranging from weak to strong pine smell.	Kern's mango nectar, 0.5 ml, added pine needles

Fermented (Overipe)	The intensity of the smell of overripe mangos, or other fruit, or fruit cider, ranging from weak to strong fermented aroma.	Kern's mango nectar (2/3) added 1/3 of Pear hard cider (ACE Perry Hard Cider)

Attributes	Definitions	Reference, intensity, preparation
	Texture	
Firmness	The amount of force required to biting completely through the sample. Place the sample between the molars and bite evenly.	Unripe mango, Tommy Atkins, firmness level: 22-23, one cm cube.
Juiciness	The amount of juice or wetness released from the sample while chewing.	Grape Berry
Fibrousness	The amount of fibers present in the sample.	Celery slice, ca. 0.5 cm
Chewiness	Number of chews required to prepare the samples for swallowing. Technique: Chew sample at a constant rate and pressure with molars until ready for swallowing; measure time or count chews to base intensity on.	Tofu piece

Attributes	Definitions	Reference, intensity, preparation
	Taste	
Sweet	Taste characteristic of sugar, mainly sucrose	Kern's mango nectar, 1 ml – only used under training

Sour (acidic)	Taste characteristic of citric acid	Unripe mango, Tommy Atkins, firmness level: 22-23. One 1 cm cube, also used as firmness standard.
Bitter	Taste characteristic of which caffeine or quinine are typical	English cucumber, removed the middle flesh, one slice, 0.5 cm.
Coconut taste	Taste of tropical fruit	Kern's nectar 0.5 ml, Mango, added coconut flakes, unsweetened, Bob's red mill – a pinch.

Mango boxes were opened and fruit of each cultivar were separated according to the firmness level. For each fruit, a number was given and besides firmness, DA meter, dry matter, tritable acidity, pH, skin and flesh color were evaluated in each fruit to a better control. Mangoes with the same firmness range were placed at the same group and some extra fruits were used in case of some internal damage.

For each cultivar, three ripening stages composed by 12 fruit were determined based on flesh firmness levels. The flesh firmness ranges used for 'Ataulfo' were 23.53-41.18N (high), 19.61-21.57N (medium) and 1.96-13.72N (low). The flesh firmness ranges used for 'Haden' were 21.57-62.76N (high), 19.61-21.56N (medium) and 7.84-9.80N (low). The flesh firmness ranges used for 'Tommy Atkins' were 11.76-15.69N (high), 8.82-9.80N (medium) and 3.92-7.84N (low). Each fruit was peeled and the mango flesh cut in halves along the contour of the seed. Half of the fruit was used for physico-chemical analysis and the other half for sensory analysis.

In the sensory analysis, each panelist received nine pieces of mango flesh. Each firmness level had three replicates, being each replicate from a different fruit to avoid the narrow range caused by just one fruit, which was also used to check each panelist liability. Samples were served on a 2 oz soufflé cup with lids, presented to the panelist randomized (Lawless and Heymann, 2010) and labeled with three-digit random codes, with water and cracker. Each cultivar was tested in a different day. The quantitative aspect or intensity expressessed the degree to which a characteristic was present and was expressed by assigning a value on a 10 cm scale. Three digit code and randomized order presented to the panelists were generated with the use of Compusense 5 Software (Compusense, 1998).

2.4 Statistical Analysis

Data statistical analysis was performed for each variable by means of analysis of variance (ANOVA) using the SAS statistical package (SAS version 9.0, Cary, NC, US). The mean values of each ripening stage (same flesh firmness range) was compared using Tukey's test ($p = 0.05$). The mean sensory attribute values were subjected to principal component analysis (PCA) using SAS (version 9.0, Cary, NC, US).

3. Results and discussion

3.1 Cultivar Ataulfo

Softening of 'Ataulfo' mangoes from 20.5 N to 7.87 N of flesh firmness is followed by an increase in Tropical Fruit and Peach Sweet Aromas and a decrease in Fermented aroma (Table 2). All other aromas evaluated were similar in fruit with different flesh firmness levels (Table 2). The specific ripe fruit aroma is determined by a diverse range and intensity of volatile compounds synthesized during ripening (Márquez et al., 2011), which together characterized the Tropical Fruit and Peach Sweet Aromas observed in 'Ataulfo' fruit. Characteristic aroma of each fruit genotype will important to determined consumer preferences and acceptance.

The results show that 'Ataulfo' mango ripening and softening is associated with reduction of fruit flesh fibrousness and chewiness, as well as increase in juiciness (Table 2). The concomitant texture changes observed during ripening are desirable to improvement eating quality of the fruit. During ripening of climacteric fruit, flesh softening is related to increase in expression and activity of cell wall degrading enzymes, as well as changes in cellular turgor pressure (Oey et al., 2007; Goulao and Oliveira, 2008). Breakdown of cell wall polysaccharides has been suggested to reduce fibrousness texture due to reduction of polysaccharide chains in fruit flesh (Goulao and Oliveira, 2008). Cell wall breakdown together and decrease in cellular turgor during softening can reduce the force required to chew and extract water from the fruit flesh, which could explain the observed lower chewiness and the higher juiciness at lower levels of fruit flesh firmness.

‘Ataulfo’ mango softening from 20.5 N to 7.87 N was followed by an increase in coconut and sweet taste and a decrease in sour taste (Table 2). Bitter taste changes were not observed during this range of fruit softening (Table 2). These results can be explained by the observed decrease in citric acid content in fruit flesh during softening (Table 3). Organic acids are the major contributors to sour taste in fruit (Da Conceicao Neta et al, 2007) In addition, reduction in acidity has also been proposed on increase the perception of sweet taste (Malundo et. al., 2001). Therefore, the observed decrease in citric acid content and TSS:TA ratio observed during softening was possibly the reason for the observed increase in coconut (tropical fruit taste) and sweet taste in 'Ataulfo' mangoes (Tables 2 and 3).

Table 2. Descriptive analysis of 'Ataulfo' mango at three firmness levels (high = 32.3 N ±5.4 s.d., medium = 20.5 N ± 0.9 s.d., low = 7.87 N ± 4.6 s.d.).

Sensory Attribute	High	Medium	Low	P-value
		Aroma		
Tropical Fruit	3.01 b*	3.05 b	4.05 a	<0.0001 **
Sweet Peach	3.04 b	3.21 b	3.95 a	0.0051 **
Citrus Fruit	2.17 a	1.87 a	2.17 a	0.4399
Green	1.74 a	1.43 a	1.78 a	0.2060
Pine	1.73 a	1.36 a	1.78 a	0.2827
Fermented	1.78 a	1.94 a	1.09 b	0.0771
		Texture		
Firmness	4.28 a	3.34 b	2.66 c	0.0009 **
Juiciness	3.21 c	3.69 b	4.22 a	<0.0001 **
Fibrousness	1.43 a	0.79 b	0.95 b	<0.0001 **
Chewiness	3.47 a	3.11 a	2.58 b	<0.0001 **
		Taste		
Sweet	3.11 b	3.52 b	4.71 a	<0.0001 **
Coconut	1.52 b	1.88 b	2.86 a	<0.0001 **
Sour	5.73 a	5.52 a	3.82 b	<0.0001 **
Bitter	2.37 a	2.15 a	2.12 a	0.5489

*Mean values with the same letter in the line: are not statistically different according to Tukey’s test (5%), n=57.

Table 3. Postharvest analysis of 'Ataulfo' mango at three firmness levels (high = 32.3 N ±5.4 Sd., medium = 20.5 N ± 0.9 Sd., low = 7.87 N ± 4.6 Sd.).

Parameter	High	Medium	Low
Firmness (N)	32.35 a*	20.59 b	7.84 c
DA Meter	0.13 a	0.07 b	0.06 b
Dry Matter (%)	22.45 b	22.23 b	23.21 a
TSS (%)	18.07 a	17.19 b	18.84 a
TA (% of citric acid)	0.99 a	0.82 b	0.56 c
TSS:TA	18.25 b	22.96 b	33.64 a
pH	3.93 a	3.53 b	3.38 c
*Skin L**	55.03 b	55.77 b	59.31 a
Skin Chroma	36.22 c	38.15 b	41.02 a
Skin Hue	96.39 a	91.68 a	89.80 a
*Flesh L**	73.75 a	74.09 a	71.49 b
Flesh Chroma	55.55 a	55.50 a	59.93 a
Flesh Hue	92.87 a	92.91 a	91.58 b

*Mean values with the same letter in the line: are not statistically different according to Tukey's test (5%).

Our data show that softening of 'Ataulfo' mangoes from 20.5 N to 7.87 N is followed by desirable changes in aroma, texture, taste and visual appearance, improving flavor and eating quality of the fruit. According to the principal component analysis, high flesh firmness is more related to sensory attributes such as firmness, fibrousness (Figure 1). Medium flesh firmness is more related to sensory attributes such as sour taste, chewiness, fermented aroma and coconut flavor (Figure 1). Low flesh firmness is more related to desirable attributes for eating purposes, such as sweet taste and tropical aroma (Figure 1). Our results show that even when 'Ataulfo' mangoes reached an average of 7.8 N of flesh firmness, the fruit still had good quality for consumption.

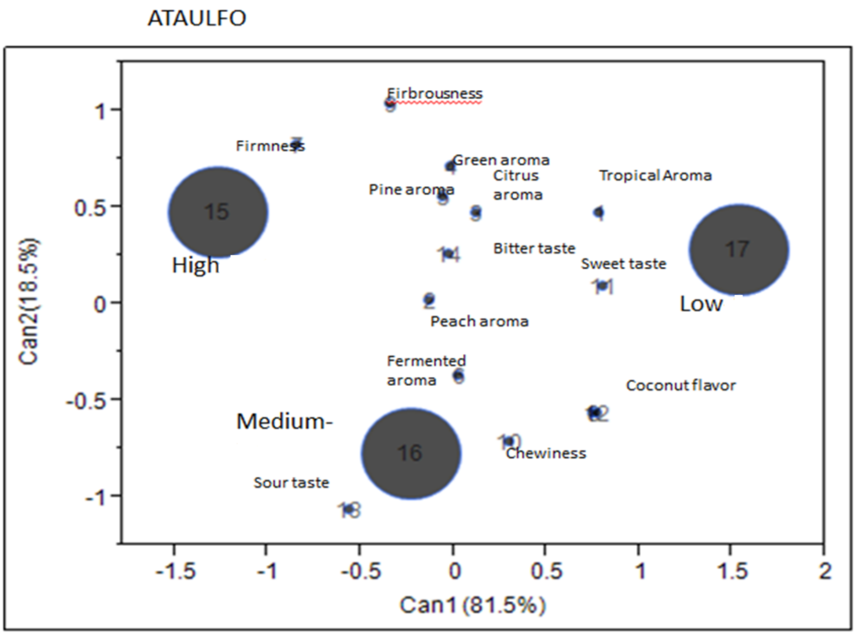

Figure 1 – Principal component analysis for sensory characteristics of ‘Ataulfo’ mangos with three firmness levels (High = 32.35N; Medium=20.59N; Low=7.84N).

3.2 Cultivar Haden

Similar to ‘Ataulfo’, mango cultivar Haden also showed an increase in tropical fruit and peach sweet aromas during softening from 42.1 N to 8.82 N of flesh firmness (Table 4). All other aromas were similar in fruit with different flesh firmness (Table 4). Aroma compounds come from several different pathways in fatty acid, amino acid, phenolic and terpenoid metabolism (Knee, 2002). As fruit ripen, characteristic aroma compounds are produced which is often coupled to ethylene synthesis in climacteric fruit, such as mangos (Schafer et al., 2007).

According to the sensory evaluation, panelist could not differentiate fruit firmness and chewiness, but instrumental flesh firmness measurements were statistically different on the three levels (Table 4). Juiciness was lower at the highest flesh firmness, increased at the medium flesh firmness and decrease at the lowest flesh firmness (Table 4). Decrease in fruit juiciness during softening has been reported to be a consequence of pectin polysaccharide metabolism, increasing its capacity to retain water and decreasing juiciness perception in fruit tissue (Brummell et al., 2004). Accordingly, these studies have also shown that further pectin polysaccharide breakdown during ripening reverses fruit juiciness possibly because short pectin chains are no longer able to strongly retain water (Brummell et al., 2004). Juiciness was constant during fruit softening from 42.1 N to 8.82 N of flesh firmness (Table 4). Panelists were able to precisely detect a reduction in chewiness during fruit softening. Softer fruit required lower force to be chewed.

Table 4. Descriptive analysis of 'Haden' mango at three firmness levels (high = 42.1 N ±5.4 s.d., medium = 20.5 N ± 0.9 s.d., low = 8.82 N ± 0.1 s.d.).

Sensory Attribute	High	Medium	Low	P-value
		Aroma		
Tropical Fruit	3.10 b*	4.21 a	4.54 a	<0.0001**
Sweet Peach	3.16 b	4.18 a	4.69 a	0.0001**
Citrus Fruit	2.30 a	1.74 a	2.22 a	0.0938
Green	1.78 a	1.57 a	1.99 a	0.1833
Pine	2.01 a	2.45 a	2.35 a	0.2677
Fermented	1.83 a	2.12 a	2.25 a	0.2749
		Texture		
Firmness	3.65 a	3.23 a	2.04 b	<0.0001**
Juiciness	6.24 b	6.84 a	6.72 b	0.0136*
Fibrousness	5.33 a	5.27 a	5.43 a	0.8661
Chewiness	3.47 a	3.10 a	2.18 b	<0.0001**
		Taste		
Sweet	3.53 c	5.33 b	6.24 a	<0.0001**
Coconut	1.48 c	2.96 b	3.68 a	<0.0001**
Sour	5.63 a	2.79 b	1.45 c	<0.0001**
Bitter	1.85 a	1.02 b	0.84 b	<0.0001**

*Mean values with the same letter in the line are not statistically different according to Tukey's test (5%), n=50.

Sweet and coconut tastes increased, whereas sour and bitter tastes decreased during 'Haden' fruit softening (Table 4). These changes can contribute to the improvement of fruit flavor and eating quality of the fruit. Similar to the 'Ataulfo' mangoes, the observed increase in coconut (tropical fruit taste) and sweet taste in 'Haden' mangoes were possibly due to the observed decrease in citric acid content and increase in the TSS:TA ratio during softening (Table 5).

During 'Haden' fruit softening, there was decrease in chlorophyll content in skin tissue, little change in dry matter and soluble solids content, decrease in citric acid content, as well as an increase in TSS:AT ratio and pH (Table 5). These changes have also been reported in other fruit, which contribute to higher flavor and eating quality (Mahmood et al., 2012). Accordingly, loss of skin green color during ripening is due to an expected activity increase of chlorophylase enzymes that accelerate chlorophyll degradation (Pakkavatmongkol, 1996). The lowest hue angle were observed in skin and flesh tissues at the lowest flesh firmness levels indicating a transition from green-yellow-orange during fruit softening (Table 5). The highest flesh and skin chromaticity was observed at the lowest flesh firmness, suggesting an increase in color intensity at the lowest flesh firmness (Table 5). It is interesting to notice that 'Haden' mangoes showed little and no changes in flesh and skin lightness during softening, respectively (Table 5). Since both skin and flesh color changes are genetically controlled, the observed changes can be used to characterize 'Haden' mango softening.

Table 5. Postharvest analysis of 'Haden' mango at three firmness levels (high = 42.1 N ±5.4 s.d., medium = 20.5 N ± 0.9 s.d., low = 8.82 N ± 0.1 s.d.).

Parameter	High	Medium	Low
Firmness (N)	42.16 a*	20.59 b	8.82 c
DA Meter	1.22 a	0.64 b	0.27 c
Dry Matter (%)	16.12 b	16.47 a	16.61 a
TSS (%)	13.34 b	14.01 a	13.87 a
TA (% of citric acid)	0.63 a	0.28 b	0.10 c
TSS:TA	23.71 c	68.00 b	167.35 a
pH	3.72 c	4.33 b	5.21 a
*Skin L**	59.09 a	60.17 a	57.80 a
Skin Chroma	43.26 b	46.86 b	49.79 a
Skin Hue	97.97 a	90.63 b	67.42 c
*Flesh L**	64.48 b	69.85 a	65.62 b
Flesh Chroma	62.83 b	66.00 a	65.87 a
Flesh Hue	83.79 b	85.38 a	82.49 c

*Mean values with the same letter in the line are not statistically different according to Tukey's test (5%).

Changes on taste attributes were more noticeable than changes on aroma attributes with different flesh firmness levels. This can be due to the fact that volatile synthesis took place before the texture changes at the time of fruit evaluation. Changes on sensory attributes such as appearance of green aroma and loss of flesh firmness have been reported during mango ripening (Suwonsichon et al., 2012). Changes on firmness during ripening have been attributed to the conversion of insoluble protopectin into soluble pectic substances, as well as the hydrolysis of fat and starch in fruit tissue (Pakkavatmongkol, 1996).

According to principal component analysis, high flesh firmness is more related to sour taste, medium flesh firmness is more related to pine aroma and juiciness, whereas low flesh firmness is more related to tropical fruit and sweet peach aromas and coconut flavor (Figure 2). The low flesh firmness of 8.82 N does not represent the ending point for consumption of ‘Haden’ mangos, since desirable characteristic were presented and undesirable attributes such as fermented aroma were not present on these mango samples (Figure 2).

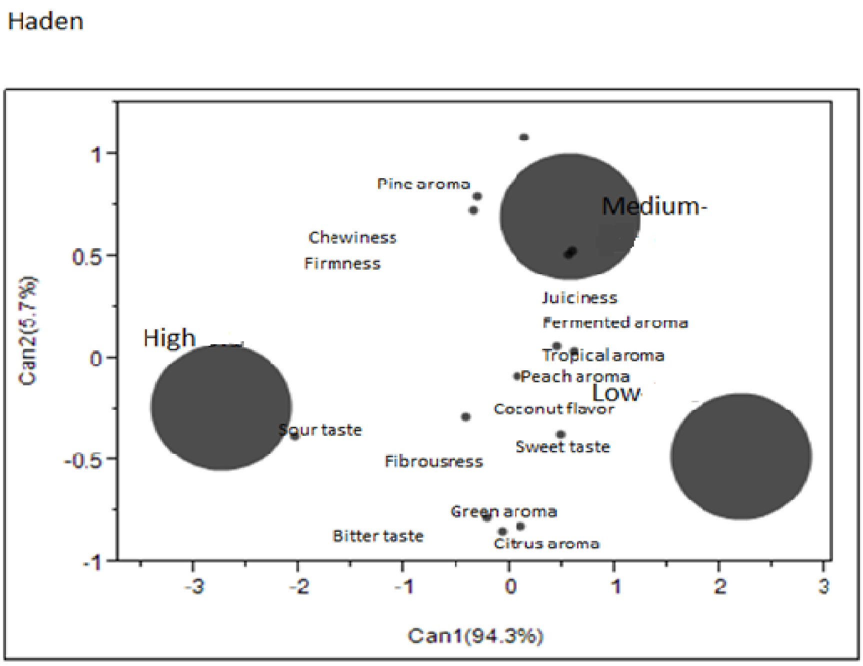

Figure 2. Principal component analysis for sensory attributes on Haden mango with three levels of flesh firmness (high= 42.1N±5.4, medium= 20.5N± 0.9, low= 8.82N±0.1).

3.3 Cultivar Tommy Atkins

The sensory descriptive analysis on three firmness levels on 'Tommy Atkins' mango was statistically different for firmness, Chewiness, Sweet Taste, Juiciness and Sour Taste (Table 6).

Table 6. Descriptive analysis of 'Tommy Atkins' mango at three firmness levels (high = 13.7 N ±0.1 s.d., medium = 9.31 N ± 0.07 s.d., low = 5.88 N ± 0.1 s.d.).

Sensory Attribute	High	Medium	Low	P-value
		Aroma		
Tropical Fruit	3.07 a*	3.30 a	3.59 a	0.0981
Sweet Peach	3.37 a	3.53 a	3.83 a	0.1670
Citrus Fruit	1.73 a	1.86 a	2.24 a	0.0822
Green	1.72 a	1.77 a	1.97 a	0.3900
Pine	1.90 a	1.58 a	1.86 a	0.2827
Fermented	1.47 a	1.59 a	1.62 a	0.7370
		Texture		
Firmness	3.55 a	3.74 a	2.77 b	<0.0001**
Juiciness	5.40 a	4.69 b	4.86 ab	0.0114*
Fibrousness	5.67 a	6.10 a	6.27 a	0.1253
Chewiness	3.48 ab	3.83 a	3.16 b	0.0061**
		Taste		
Sweet	3.26 b	3.74 ab	3.77 a	0.0286*
Coconut	2.04 a	1.97 a	2.24 a	0.3975
Sour	2.72 a	1.83 b	1.57 b	<0.0001**
Bitter	1.58 a	1.24 a	1.28 a	0.0897

*Mean values with the same letter in the line: are not statistically different according to Tukey's test (5%), n=62.

Juiciness was higher at the highest flesh firmness, and chewiness was lower in sampes with low flesh firmness on 'Tommy Atkins' mangoes (Table 6).

According to the sensory evaluation, panelist could not differentiate fruit fibrousness (Table 6), that was constant during fruit softening from 13.7N to 5.88N of flesh firmness (Table 6). Panelists were able to precisely detect a reduction in chewiness during fruit softening. Softer fruit required lower force to be chewed. Fruit softening during ripening is a major quality attribute that often dictates shelf-life and could arise from loss of turgor, degradation of starch or breakdown of the mango cell wall, being the last the most important change (Knee, 2002).

Not only for Tommy Atkins mangos, but also for Ataulfo and Haden cultivars, notes for the attributes did not achieve the highest values of the 10 point scale and this can be due because the samples did not have the same sensory attributes intensity than the standards, and the panelists used the scale properly.

According to the panelists, Sour Taste and Sweet Taste received had different intensity according to flesh firmness (2.72 and 3.26 on 10 point hedonic scale for firmer (13.75 N) samples) (Table 6). The other taste attributes evaluated were not different when the firmness of the samples changed.

The analysis of postharvest characteristics on ‘Tommy Atkins’ mangoes with three firmness levels on ‘ready to eat’ fruit are presented on Table 7.

Table 7. Postharvest analysis of 'Tommy Atkins' mango at three firmness levels (high = 13.7 N ±0.1 s.d., medium = 9.31 N ± 0.07 s.d., low = 5.88 N ± 0.1 s.d.).

Parameter	High	Medium	Low
Firmness (N)	13.75 a	9.31 b	5.88 c
DA Meter	1.00 b	1.90 a	0.75 c
Dry Matter (%)	12.39 b	12.73 b	13.58 a
TSS (%)	10.24 b	10.36 b	19.46 a
TA (% of citric acid)	0.22 a	0.17 b	0.18 b
TSS:TA	51.53 b	66.72 b	139.86 a
pH	4.36 c	4.54 a	4.46 b
*Skin L**	55.59 b	55.60 b	59.53 a
Skin Chroma	36.58 b	37.98 b	41.32 a
Skin Hue	93.05 a	92.73 a	89.88 a
*Flesh L**	73.66 a	73.97 a	71.58 b
Flesh Chroma	5.93 a	55.83 a	56.71 a
Flesh Hue	92.76 a	92.81 a	91.60 b

*Mean values with the same letter in the line: are not statistically different according to Tukey’s test (5%).

'Tommy Atkins' mangoes softening from 13.7N to 5.88N was observed and less chlorophyll content measured by DA meter and less acidity was presented on softer fruit. TSS and TSS:TA ratio were higher in 'Tommy Atkins' fruit with low firmness, compared to fruit with medium and high firmness. Sweetness is related mainly to sugar contents, which include sucrose, glucose, fructose and even sorbitol (Knee, 2002). Among the sugars, fructose is considered sweeter than sucrose, which is sweeter than glucose. The two major pathways in plants are photosynthesis and respiration. Sugars are derived from photosynthesis while acids are generated in respiration reactions in the tricarboxylic acid cycle (Knee, 2002).

The observed decrease in citric acid content in fruit flesh during softening can explain changes in Sour Taste and Swwet Taste presented on Table 6. Organic acids are the major contributors to sour taste in fruit (Da Conceicao Neta et al, 2007) In addition, reduction in acidity has also been proposed on increase the perception of sweet taste (Malundo et. al., 2001).

The principal component analysis (PCA) for the sensory attributes on 'Tommy Atkins' mangoes is shown on Figure 3. Samples with medium (9.31N) firmness are positively correlated with Chewiness and Sweet Taste, being a mix of attributes expected for high and low firmness samples, respectively. Green and Tropical Aroma, Firmness and Coconut Flavor are related to low flesh firmness mangos.

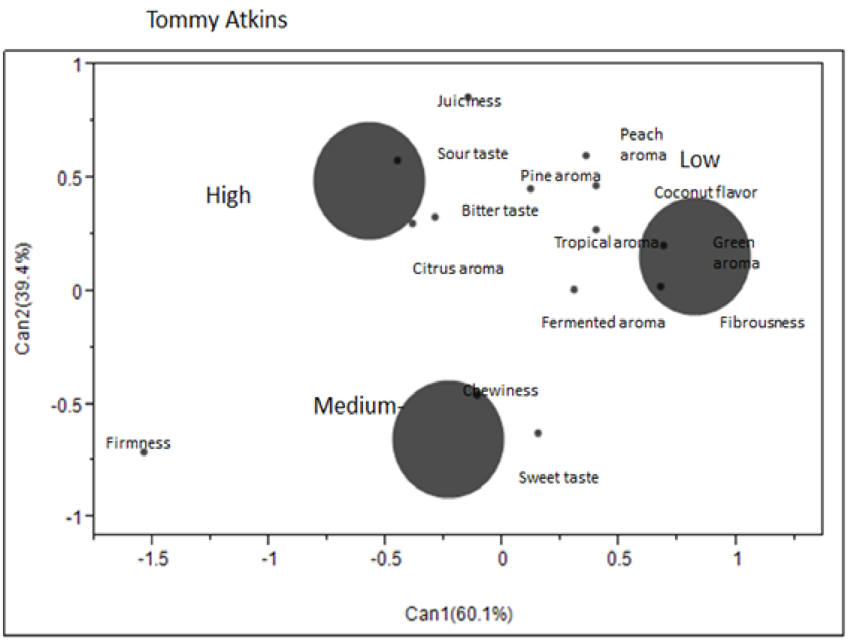

Figure 3. Principal component analysis for sensory attributes on 'Tommy Atkins' mango with three levels of flesh firmness (high =13.7N±0.1, medium= 9.31N±0.07, low= 5.88N±0.1).

4. Conclusions

'Ataulfo' mangos with high flesh firmness are better described by higher sensory firmness, whereas fruit with lower flesh firmness are better characterized by Sweet Taste and Tropical Aroma.

'Haden' mangoes with high flesh firmness are better characterized by Sour Taste, whereas fruit with lower flesh firmness are better characterized by Sweet Taste.

'Tommy Atkins' mangoes with high flesh firmness are well characterized by Sour Taste, whereas fruit with lower flesh firmness are better characterized by Green and Tropical Aromas and Coconut Flavor.

'Ataulfo', 'Haden' and 'Tommy Atkins' fruit with 7.84, 8.82, 5.88 N of flesh firmness respectively, still had an acceptable quality for consumption.

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