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A comparative evaluation of maturity indices of mango fruits produced in two contrasting agro-ecological zones of Kenya

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Abstract

Harvesting mango (*Mangifera indica*) fruits at the right stage for the destination market and use requires reliable maturity indices. There are various indices that are used to determine harvest maturity for mango fruits. However, differences in cultivars and growing environment affect the reliability of these indices. The present study was conducted to establish maturity indices of two popular mango varieties, 'Apple' and 'Ngowe'. The study was conducted in two contrasting agro-ecological zones (AEZs) of Kenya namely Embu County (a high potential AEZ) and Makueni County (a low potential AEZ). For each variety, the earliest physiological maturity was determined using flesh color. The flesh color was established by cutting the fruits longitudinally to expose the cross sectional view. The earliest physiological maturity (stage 1) was marked as the stage when the flesh was mostly cream and turning yellow at the seed. The number of days after full bloom was matched to this maturity stage (stage 1) and subsequent maturity stages determined at 10-day intervals as stages 2, 3 and 4. For each of the maturity stages, physiological (ethylene evolution and respiration rates); physical (size, peel/flesh firmness and peel/flesh color) and biochemical (Total soluble solids - TSS, Total titratable acidity – TTA and TSS:TTA ratio) maturity indices were determined. The results show that in both varieties ('Apple' and 'Ngowe') from both locations (Embu and Makueni), respiration rates increased gradually with maturity. 'Ngowe' and Makueni fruits registered the higher respiration and ethylene evolution rates compared to 'Apple' and Embu fruits for the same maturity stage. As maturation progressed, peel firmness decreased gradually irrespective of variety or production location. In all fruits, flesh color (hue angle) decreased gradually with maturity. Total soluble solids increased while TTA decreased gradually with maturity. Overall, in both varieties, Makueni fruits attained comparable maturity indices to Embu fruits at an earlier stage/date. The results revealed the significant effect of production location on the maturity indices of mango fruits. There is need for additional studies to establish reliable maturity indices for other commercial varieties produced under different AEZs.

Key words: AEZ, apple mango, harvest, maturity indices, Ngowe

Résumé

La récolte de fruits de mangue (*Mangiferaindica*) au bon moment pour le marché de destination et l'utilisation nécessite des indices fiables de maturité. Il existe différents indices qui sont utilisés pour déterminer la maturité de récolte pour les mangues. Cependant, les différences de cultivars et de l'environnement influent de plus en plus sur la fiabilité de ces indices. La présente étude a été menée pour établir des indices de maturité de deux variétés de mangue populaires, «pomme» et «Ngowe». L'étude a été menée en deux zones agro-écologiques contrastées (ZAE) du Kenya à savoir le comté d'Embu (un fort potentiel AEZ) et le comté de Makueni (un faible potentiel AEZ). Pour chaque variété, la première maturité physiologique a été déterminée en utilisant la couleur de la chair. La couleur de la chair a été créée en coupant les fruits longitudinalement à exposer la vue en coupe transversale. La première maturité physiologique (stade 1) a été marquée comme le stade où la chair est principalement crème et tournant jaune à la graine. Le nombre de jours après la pleine floraison a été adapté à ce stade de maturité (stade 1) et les stades de maturités suivantes déterminées à intervalles de 10 jours comme les étapes 2, 3 et 4. Pour chacun des stades de maturité, physiologique (évolution de l'éthylène et le taux de respiration); physiques (taille, peau / fermeté de la chair et la couleur pelure / chair) et biochimique (le total des solides solubles - TSS, le totale d'acidité traitable - TTA et TSS: le rapport de TTA) les indices de maturité ont été traités. Les résultats montrent que dans les deux variétés («pomme» et «Ngowe ') à partir de deux endroits (Embu et Makueni), le taux de respiration a augmenté progressivement avec la maturité. Les fruits de «Ngowe 'et de Makueni avaient enregistré les plus de respiration et le taux de l'évolution de l'éthylène par rapport à la«pomme»et aux fruits d'Embu pour le même stade de maturité. Comme la maturation progresse, la dureté de l'écorce fermeté a diminué progressivement, indépendamment de la variété ou de lieu de production. Dans tous les fruits, la couleur de la chair (angle de teinte) a diminué progressivement avec la maturité. Les solides totaux solubles augmentent tandis que TTA diminue progressivement avec la maturité. Globalement, dans les deux variétés, les fruits de Makueni atteignent des indices de maturité comparables aux fruits Embu lors d'une précédente étape / jour. Les résultats ont révélé l'effet significatif de l'emplacement de production sur les indices de maturité des mangues. La necessité de faires des études supplémentaires pour établir des indices de maturité fiables pour d'autres variétés commerciales produites dans différentes zones agro-écologiques.

Mots clés: AEZ, pomme mangue, récolte, indices de maturité, Ngowe

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Background

Fruit maturity at harvest is a key determinant of the flavor and keeping quality of the fruits. In most fruits, quality is maximized when the fruits are harvested more mature or ripe, whereas shelf and storage life are extended if they are harvested less mature or unripe (Toivonen, 2007). The selection of suitable maturity indices for harvest is very important in balancing between shelf life and quality. It is also important in identifying the right maturity for different markets and uses of the fruits. Fruits harvested at early maturity are firmer, less prone to mechanical damage and generally have a longer shelf life – an important

attribute for distant markets. However such fruits often fail to ripen adequately to achieve optimal eating qualities and are also more sensitive to chilling injury during cold storage (Yahia, 1998). On the other hand, fruits harvested at advanced maturity stage may have superior eating quality but have a short shelf life. Such fruits of advanced maturity are highly susceptible to mechanical damage such as bruising, decay and water loss, resulting in quality deterioration. Over mature fruits also show defects like jelly seeds or jelly pulp after harvest (Yahia, 1998). Knowledge of the right maturity indices for different markets is important for all supply chain actors. For the producers, knowledge of maturity indices guides them to harvest at the right stage for the target market thereby minimizing rejections (culling) at the market stage. For packing house operators and traders, sorting based on maturity stage is necessary to improve uniformity of ripening lots of fruits at destination. Knowledge of the stage of maturity (ripeness) is also important for designing the optimal postharvest handling strategy (Slaughter, 2009).

Physical, physiological, biochemical and Chronological indices are used to establish the maturity of fruits. Physical methods used to determine maturity in mango include softness (firmness) and fullness of the cheeks, peel/flesh colour, shoulder position, and specific gravity (Kosivachinda *et al*., 1984). Physiological indices include respiratory activity and ethylene evolution rate. In climacteric fruits such as mango, respiration and ethylene evolution increase gradually after physiological maturity to peak levels as the fruits ripen and then decline gradually. Biochemical maturity indices include total soluble solids content (TSS) and titratable acidity (TTA). In mango, during fruit maturation TSS tends to increase while TTA decreases (Madigu, 2010). Age of the fruit calculated from full bloom or fruit set is also considered a simple chronological method to confirm maturity (Yahia, 1998). However the age of the fruit at a certain harvest maturity (based on days after full bloom or fruit set) varies according to different varieties, geographical regions and cultivation conditions (Sivakumar, 2011). Generally, the various indices are independently unreliable as they are greatly affected by other factors. Therefore determination of harvest maturity conclusively requires a combination of several indices.

In Kenya, mango fruits (different varieties) are produced across a wide range of agro-ecological zones ranging from sub-humid (high potential) to semi-arid (low potential). These diverse production environments variably affect fruit growth and development and ultimately determine time taken to maturity.

Objectives

The objective of this study was to establish maturity indices (physical, physiological and biochemical) of two popular mango varieties ('Apple' and 'Ngowe') produced in two contrasting different agro-ecological zones in Kenya; Embu County and Makueni County.

Study description

The study was conducted in two contrasting agro-ecological zones (AEZs) of Kenya namely Embu County and Makueni County. Embu County is semi-humid and high potential AEZ

(III) which lies at an altitude of 1200 m above sea level. The region has a mean annual temperature of 19°C with the annual rainfall ranging between 950 mm to 1350 mm. Makueni County is a low potential AEZ (V) that lies at 450 m above sea level and receives an annual average rainfall of 550 mm or less. The mean annual temperature varies between 26°C to 35°C.

For each variety, 12 mango trees (age 6 – 8 years) were selected from commercial farms in the two locations and tagged. The earliest physiological maturity was determined using flesh color (mostly cream and turning yellow at the seed). The number of days from 50% flowering to this stage was also determined. This early maturity stage (designated stage 1) was used as a reference point for subsequent stages determined at 10-day intervals as stage 2, 3 and 4. For each variety (from each of the two locations) various indices of maturity were established for the 4 stages. The indices established include physiological (ethylene evolution and respiration rates); physical (size, peel/flesh firmness and peel/flesh color) and biochemical (total soluble solids, total titratable acidity and TSS:TTA ratio). The parameters were determined using standard procedures/protocols.

Results

In both mango varieties ('Apple' and 'Ngowe') regardless of location, respiration rates increased gradually with stage of maturity, from 34.4 - 38.2 mg/Kg/Hr (stage 1) to 39.8 - 64.72 mg/Kg/Hr (stage 4). Higher respiration and ethylene evolution rates were observed in 'Ngowe' and Makueni fruits compared to 'Apple' and Embu fruits for the same maturity stage. Peel firmness decreased with advancement in maturity from 52.2 - 54.6 N (stage 1) to 6.1 - 24.6 N (stage 4). The same trend (declining firmness) was observed in the flesh. In all fruits, flesh color (hue angle) decreased gradually with maturity, from approximately 97^0 (stage 1) to 77.8 - 89.1^0 (stage 4). In stage 3 and 4, Makueni fruits (both varieties) had significantly lower hue angles compared to Embu fruits. Irrespective of location, 'Ngowe' fruits generally had higher TSS:TTA ratio compared to 'Apple' fruits for the same maturity stages. In both varieties, generally higher TSS:TTA ratios were observed in Makueni fruits for the same stages of maturity. Overall, in both 'Apple' and 'Ngowe', Makueni fruits attained comparable maturity indices to Embu fruits at an earlier stage/date (Table 1).

Discussion

Preharvest production conditions significantly affect plant growth and development and consequently the time taken to maturity (Slaughter, 2009; Sivakumar, 2011). In the present study, it was evident that advancement to full maturity (stage 4) was affected by the AEZ and variety. It took 10 days more to attain the earliest maturity (stage 1) in Embu compared to Makueni. Similarly, in both varieties, comparable maturity indices for all the stages were attained earlier in Makueni fruits compared to Embu fruits. This was evidenced by lower firmness, hue angle, and TSS:TTA ratio in Makueni fruits compared to Embu fruits for the same stage of maturity. Similarly, higher respiration and ethylene evolution rates were observed in Makueni fruits compared to Embu fruits for the same maturity. The findings underscore the unreliability of generalized maturity indices that do not take into account the production

Table 1. Maturity indices' matrix for 'Apple' and 'Ngowe' mango varieties harvested from Embu and Makueni Counties of Kenya.

Mango variety	Production region	Maturity stage	Days after full bloom (DAFB)	Flesh firmness (Newtons)	Flesh colour Hue angle (°)	TSS:TTA ratio
Apple	Makueni	1	101	25.1d	97.8a	18.0
Apple	Embu	1	111	28.3b	97.9a	13.4
Ngowe	Embu	1	97	32.7a	97.5a	27.1
Apple	Makueni	2	111	15.3c	95.4a	21.0
Apple	Embu	2	121	22.3b	92.9a	22.8
Ngowe	Makueni	2	101	20.6b	88.5b	48.2
Ngowe	Embu	2	107	27.8a	94.6a	44.6
Apple	Makueni	3	121	9.3c	87.2b	31.9
Apple	Embu	3	131	15.6b	91.5a	29.5
Ngowe	Makueni	3	111	13.0b	85.5b	56.4
Ngowe	Embu	3	117	20.8a	91.3a	48.2
Apple	Makueni	4	131	4.6c	77.8c	68.2
Apple	Embu	4	141	7.5a	88.7a	54.5
Ngowe	Makueni	4	121	6.6b	80.1b	97.7
Ngowe	Embu	4	127	6.5b	89.1a	112.8

*Values presented in the table are means of 5 fruits individually analyzed. Means followed by the same letter in a column (for each maturity stage) are not significantly different by Fisher's least significant difference test at $p<0.05$.

environment and varietal differences. For a fruit that is well adapted to diverse AEZs, there is need to generate a maturity indices matrix combining physiological, physical and biochemical indices for all the commercial varieties. Reliable maturity indices are of importance to all supply chain actors to ensure proper sorting for the different markets and/or uses (Slaughter, 2009).

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