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Selection of sweetpotato clones with high ß-carotene for processing of nutritious food products

(Pemilihan klon ubi keledek dengan kandungan ß-karotena yang tinggi untuk pemprosesan produk makanan berkhasiat)

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Key words: *Ipomoea batatas*, sweetpotato, selection, ß-carotene, juice

Abstract

ß-carotene, a precursor of Vitamin A, can be easily found in sweetpotato germplasm. While carrot, one of the traditional sources of ß-carotene, cannot grow in the tropical humid lowlands of Malaysia, sweetpotato thrives. In an attempt to partially substitute the imports of carrot and to popularize the use of orange sweetpotato in wholesome food products, a breeding and selection programme for sweetpotato clones with ß-carotene was initiated by MARDI. A series of trials was carried out on 13 clones together with two checks over six sites, one each located on tin-tailings and acid sulphate soils, and two sites each on upland mineral soils and *bris*. Combined analyses of variance showed that clones Merah Manis, Tainung No. 64, Guan and Caromex all gave root yields in excess of 15 t/ha after 3½–4 months, with Merah Manis (26.2 t/ha) significantly outyielding the check Gendut (15.8 t/ha) over the six sites. Caromex, which ranked third or fourth at the marginal soil sites, had a higher ß-carotene content (6.18 mg/100 g) than the check Kuala Bikam 2 (5.81 mg/100 g). Initial testing of the four shortlisted clones for making juice showed promise in terms of taste and colour. With further product development work, this may lead to popularizing orange sweetpotato juice in place of carrot juice. Similarly, there is potential in using sweetpotato flour in place of wheat flour in making a more nutritious cake.

Introduction

Beta-carotene, a precursor of Vitamin A, is an important antioxidant occurring in many orange-coloured fruits and vegetables. Sweetpotato *(Ipomoea batatas)* can be a richer source of ß-carotene than even carrot (Holland et al. 1991). Currently, the consumption of foods naturally high in antioxidants such as ß-carotene and vitamins as part of the daily diet is recommended over reliance on food or health supplements. Thus, the selection of sweetpotato varieties high in ß-carotene serves to provide consumers with the choice of another wholesome vegetable and the food processing industry with a nutritious raw material for use in making healthy food products.

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In addition, having varieties rich in ß-carotene will upgrade the status of sweetpotato from its current status as a minor root crop, targeted almost solely for the fresh market, to an agro-industrial raw material with good demand.

Currently, most of the local cultivars in Malaysia have root flesh which is white or pale yellow. High ß-carotene types, characterized by orange flesh, are easily found in sweetpotato germplasm. Carrot, the traditional source of ß-carotene, unlike sweetpotato cannot be grown in the lowlands of tropical Malaysia. Carrot imports amounted to more than 15,000 tonnes a year, valued at RM64.6 million in 2000 (Anon. 2002). The VITAA (Vitamin A for Africa) project coordinated by the International Potato Center has shown success in overcoming vitamin A deficiency among children by feeding them with orange-fleshed sweetpotato (Anderson et al. 2003). While vitamin A deficiency is not a critical issue in Malaysia, nevertheless, high ß-carotene varieties may be used in the following manner:

- Fresh use in cooking, juices, etc. as a partial substitute of carrot
- Processing into nutritious flour for subsequent processing into food products

Materials and methods

Sweetpotato accessions with ß-carotene content were assembled from introductions from the National Agricultural Research Center for Kyushu and Okinawa (KONARC), Japan and the International Potato Center (CIP), Peru in 1997, as well as locally collected farmer varieties. Preliminary evaluation and selection at MARDI Headquarters, Serdang, shortlisted the entries to 13 *(Table 1)*, and these were tested against two local checks, Gendut (for yield) and Kuala Bikam 2 (for ß-carotene content) in a series of trials sited in contrasting agro-ecologies. These were Serdang and Seberang Perai on upland mineral soils, Telong and Kandis on sandy beach deposits (known as *bris*), Kuala Bikam on tin-tailings (specifically on the sand-tailings fraction) and Kuala Linggi on acid sulphate soils. Except for Serdang and Seberang Perai, the four remaining sites are considered marginal areas for crop cultivation, but have been shown to support sweetpotato crops given the necessary soil ameliorative measures (Tan et al. 2000).

The trials set out in randomized complete block design were each replicated four times, and for each entry a plot size of 20 m^2 with a plant spacing of 25 cm

Table 1. Thirteen sweetpotato clones containing ß-carotene and their origin

Clone	Origin	Institution
Bugs Bunny	Puerto Rico	CIP
Caromex	USA	CIP
Tainung No. 64	Taiwan	CIP
Resisto	USA	CIP
W-213	USA	CIP
Julian	USA	CIP
W-154	USA	CIP
Travis	USA	CIP
W 219	USA	CIP
Benihayato	Japan	KONARC
PP INA	Indonesia	Farmer's field
Merah Manis	Malaysia	Farmer's field
Guan	Malaysia	Farmer's field
Checks		
Gendut – for root yield	Malaysia	MARDI
Kuala Bikam 2 – for carotene content	Malaysia	Farmer's field

and rows spaced 100 cm apart was used. Standard fertilizer rates and soil amelioration practices for the different agro-ecologies were used (Tan 2002). The trials were repeated for a second season at the one of the sites on *bris* and on acid sulphate soils.

At harvest (3½–4 months), data were collected on total fresh root yield as well as yield of marketable roots (greater than 150 g each), harvest index (fresh root weight divided by total fresh plant weight) and root dry matter content. Root dry matter content was determined from chopped-up 100 g samples of fresh roots, oven-dried at 70 °C until constant weight.

A combined ANOVA, using the SAS statistical package, was carried out using a single season's data over the six sites on four agro-ecologies (over five sites for harvest index). Another combined ANOVA was carried out on the two seasons' data on marketable and total root yields collected on one of the sites on *bris* (Kandis) and on acid sulphate soils. This was to determine if season produced significant effects on the performance of the clones.

ß-carotene contents of the four best entries and the ß-carotene check, Kuala Bikam 2, from the first season's trial on acid sulphate soils were also determined.

Some preliminary testing of root samples of the ß-carotene clones for food processing was carried out. Samples from the four highest yielding clones together with orange variety Kuala Bikam 2 were evaluated for their suitability in making juice (3 parts of sweetpotato to 1 part of water + citric acid). Also, the nutrient compositions of flours processed from three of the top clones were compared with flour from Kuala Bikam 2. Flour from the highest yielding clone was used in a cake recipe to replace wheat flour.

Results and discussion

Performance of clones in different agro-ecologies

The combined ANOVA over the six sites on four agro-ecologies *(Table 2)* shows that the Merah Manis clone had the highest total fresh root yield, followed by Guan, Tainung No. 64 and Caromex. Merah Manis also ranked first in all the six sites over four agro-ecologies *(Table 3)*. The same trend was observed for marketable root yields. All the four clones had significantly higher total and marketable root yields compared to Kuala Bikam 2, the ß-carotene check. Only Merah Manis and Guan outperformed Gendut, the yield check, for these two traits, while Tainung No. 64 had a significantly higher marketable root yield.

Of the four top-yielding clones, Merah Manis and Caromex had superior harvest indices compared to the checks, implying a more efficient channelling of dry matter towards the organs of economic importance, namely the storage roots.

Merah Manis, Guan, Tainung No. 64 and Caromex had dry root matter content ranging from 22.8–24.5%. Except for the higher value of Caromex, these values were significantly lower than that of the check, Kuala Bikam 2 (26.0%), but not significantly different from that of the check, Gendut.

Merah Manis and Guan are local clones among those which were collected from farmers' fields (and obviously showed good local adaptation), while Caromex and Tainung No. 64 originated from the USA and Taiwan, respectively. Except for Caromex, the clones of the USA origin were generally not outstanding in yield.

Although there were significant site effects, and despite their contrasting edaphic characteristics, the trial sites on the marginal soils, such as *bris*, acid sulphate soils and tin-tailings produced mean root yields no worse than the better site on upland mineral soils *(Table 3)*. The poorer site on upland mineral soils (Seberang Perai) recorded a significantly lower mean root yield, while one of the *bris* sites (Kandis) produced the significantly highest mean root yield. Indeed, Merah Manis was able to produce fresh root yields ranging from 36.0–41.1 t/ha on acid sulphate and *bris* soils, respectively.

Table 2. Performance of 15 sweetpotato clones with ß-carotene content over six sites on four contrasting agro-ecologies

Clone	Total fresh root yield (t/ha)	Marketable fresh root yield (t/ha)	Harvest index*	Dry matter content (%)
Bugs Bunny	10.0e	6.3f	0.30de	23.7def
Caromex	15.7c	8.4e	0.52a	24.5cd
Tainung No. 64	17.8bc	13.0c	0.44bc	23.4defg
Resisto	5.8g	2.7g	0.27ef	28.6a
W-213	6.6fg	3.4g	0.29def	27.9b
Julian	8.4ef	2.0g	0.33de	22.7efg
W-154	7.6efg	3.5g	0.23f	23.2defg
Travis	9.0ef	3.1g	0.53a	22.1fg
W 219	12.8d	6.8ef	0.33d	22.0g
Benihayato	9.0ef	5.6f	0.30de	27.3ab
PP INA	9.0ef	5.6f	0.46b	25.9bc
Merah Manis	26.2a	19.5a	0.57a	22.8efg
Guan	18.8b	16.3b	0.45bc	23.4defg
Gendut**	15.8c	11.1d	0.40c	24.1de
Kuala Bikam 2**	8.0efg	5.7f	0.31de	26.0bc
Mean	12.0	7.5	0.38	24.4
CV (%)	33.4	44.4	23.2	10.4

*Mean over five locations only (Kuala Linggi, Serdang, Seberang Perai, Telong, Kuala Bikam)
**Checks
Means within the same column bearing the same letter are not significantly different from one another at $p = 0.05$ according to DMRT

Table 3. Yields (t/ha) and ranking of top five sweetpotato clones with ß-carotene content in six sites on four agro-ecologies

Clone	Upland mineral		*Bris*		Tin-tailings	Acid sulphate
	Serdang	S. Perai	Telong	Kandis	K. Bikam	K. Linggi
Merah Manis	28.2 (1)*	16.2 (1)	41.1 (1)	39.2 (1)	23.8 (1)	36.0 (1)
Tainung No. 64	18.6 (4)		16.0 (3)			28.4 (2)
Guan	23.5 (3)	6.5 (2)	18.9 (2)	36.6 (2)	17.5 (2)	
Caromex				30.5 (3)	12.3 (4)	23.2 (3)
Gendut	25.0 (2)			21.2 (5)	12.5 (3)	18.8 (4)
Kuala Bikam 2	13.4 (5)					
W-154			14.9 (5)			
Travis		1.9 (5)	16.0 (4)			
Julian						18.3 (5)
Benihayato					10.5 (5)	
W-219		5.3 (3)		22.7 (4)		
Bugs Bunny		3.1 (4)				
Site mean	13.4 b	2.7 d	13.7 b	19.9 a	8.4 c	14.0 b

*Figures in brackets refer to the ranking
Site means bearing the same letter are not significantly different from one another at $p = 0.05$ according to DMRT

Plate 1. Root characteristics of Merah Manis, the highest yielding of the ß-carotene clones

Plate 2. Shoot and leaf characteristics of Merah Manis

The morphological characteristics of Merah Manis are given in *Plates 1* and *2*, as well as in the *Appendix 1*.

Performance of clones over two seasons

The combined ANOVA using data from one of the bris sites and the acid sulphate site shows that season had significant effects on marketable root yield but not on total root yield. Nevertheless, there were significant season x clone effects on both traits *(Table 4)*.

Yield-wise, the four clones (Merah Manis, Guan, Caromex and Tainung No. 64) still ranked the top four, but in a different ranking order. Merah Manis and Guan once again produced significantly higher marketable root yields, an important consideration if these clones are to be grown for table use.

Table 4. Performance of 15 sweetpotato clones with ß-carotene content at two contrasting agro-ecologies over two seasons

Group	Total fresh root yield (t/ha)	Marketable fresh root yield (t/ha)
Clone		
Bugs Bunny	13.7ef	9.3c
Caromex	27.7ab	17.2b
Tainung No. 64	25.1bc	19.0b
Resisto	10.1fg	5.8de
W-213	8.3g	5.6de
Julian	11.6fg	2.5e
W-154	11.4fg	5.8de
Travis	12.4ef	4.7de
W 219	18.3d	11.1c
Benihayato	12.0efg	8.0cd
PP INA	15.6de	10.6c
Merah Manis	30.0a	23.6a
Guan	27.9ab	25.3a
Gendut*	23.9c	18.4b
Kuala Bikam 2*	10.2fg	8.0cd
Site		
Bris	19.2a	12.9a
Acid sulphate	15.2b	10.4b
Season		
Season 1	17.0a	10.4b
Season 2	17.4a	12.9a
Site x season	**	NS
Site x clone	**	**
Season x clone	**	**
Site x season x clone	**	**

*Checks

Means within the same column within the same group bearing the same letter are not significantly different from one another at $p = 0.05$ according to DMRT

NS = Not significant;

** = Significant at $p = 0.01$

It is interesting to note that Merah Manis also outperformed the currently popular orange-fleshed table variety, PP INA, which is imported from Indonesia. PP INA was only able to produce both total and marketable yields which were about one-third to half of those of Merah Manis.

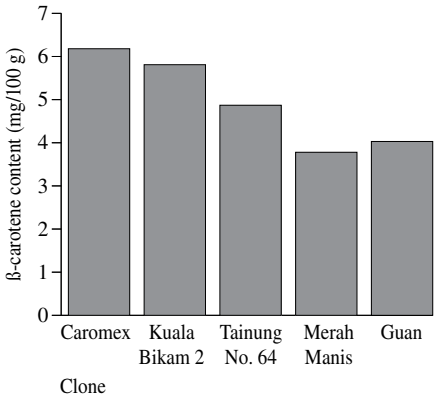

Figure 1. ß-carotene content of the top four clones including the check Kuala Bikam 2 in root samples collected from the acid sulphate site

Plate 3. Juice made from shortlisted sweetpotato clones (From left to right: Caromex, Kuala Bikam 2, Tainung No. 64, Merah Manis, Guan)

ß-carotene content of selected clones and preliminary processing

In terms of ß-carotene content, only Caromex had a higher value than Kuala Bikam 2, the check for ß-carotene content *(Figure 1)*. Nevertheless, these values compare favourably with the ß-carotene content of carrot at 3.2 to 6.6 mg/100 g (Tee et al. 1997; Pfander 1998). Furthermore, juices made from the five clones were generally acceptable in taste, with Guan ranking highest, followed by Tainung No. 64 and Caromex. Juice made from Kuala Bikam 2 was rather bland. *Plate 3* shows the range in intensity of the orange colour in the juices.

Flour was made from the three highest yielding clones, viz. Merah Manis, Guan and Caromex. A comparison of the nutrient composition of the flours with the flour of the orange check variety Kuala Bikam 2 *(Table 5)* showed that flour from Guan had the highest crude protein content (1.83%), while flour from Caromex had the highest vitamin C content (2.49 mg/100 g). Vitamin A contents of the flours of Merah Manis and Caromex although not higher than that of Kuala Bikam 2, their values were comparable.

Flour of Merah Manis was also used to replace wheat flour in a cake recipe. The nutrient compositions of both the flour and cake compared to wheat flour and its corresponding cake are given in *Table 6*. Compared to a cake made from wheat flour, the sweetpotato cake appears to be moister, has equivalent protein and fat contents, and has the added bonus of containing dietary fibre and ß-carotene, both of which are not present in wheat flour.

Table 5. Nutritional analyses of four sweetpotato clones used for making flour (per 100 g)

Nutrient content	Guan	Merah Manis	Caromex	Kuala Bikam 2
Crude protein (g)	1.83	1.20	0.98	0.85
Crude fat (g)	0.15	0.22	0.33	0.22
Dietary fibre (g)	2.25	2.49	2.49	2.89
Starch (g)	14.74	13.90	14.74	16.17
Vitamin C (mg)	1.44	1.33	2.49	1.53
Vitamin A (μg) (as ß-carotene)	745.50	2066.00	1904.00	2250.00
Energy (kcal)	104.30	87.70	112.90	104.50

Source: Salma and Zaidah (2006)

Table 6. Nutrient composition of sweetpotato and wheat flours and their corresponding cakes

Type of flour/cake	Moisture	Crude protein	Crude fat	Crude fibre	Dietary fibre	Vitamin C	ß-carotene	Energy (kcal)
	----------	----------	g/100 g	----------		-----	mg/100 g	----
Sweetpotato flour	6.6	2.9	0.5	4.50	9.70	18.0	7.48	362
Wheat flour*	12.5	12.0	1.6	2.00	n.a.	0.0	0.00	345
Sweetpotato cake	40.1	6.0	18.1	0.89	5.08	n.a.	2.48	321
Wheat cake*	14.8	7.1	19.8	0.00	n.a.	n.a.	0.00	435

*Source: Tee et al. (1997)
n.a. = Not analysed

Conclusion

Evaluation over six sites on four agro-ecologies of sweetpotato clones having roots with high ß-carotene was successful in shortlisting four which have reasonable root yields compared to the check, Gendut. While only Caromex had a ß-carotene content higher than the second check, Kuala Bikam 2, all four outyielded this check significantly. Merah Manis was outstanding in yield in all the test sites.

Initial testing also showed the possible use of these clones for making juice. A more nutritious cake can be made from the flour of Merah Manis compared to wheat flour. Such favourable results pave the way to developing orange-fleshed sweetpotato into a range of high-carotene food products.

The marginal sites on *bris*, tin-tailings and acid sulphate soils were able to produce sweetpotato yields at par with the better site on upland mineral soils; indeed, one of the *bris* sites recorded the highest mean root yield.

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Abstrak
ß-karotena, yang bertukar menjadi vitamin A apabila dimakan, boleh ditemui dengan mudah dalam janaplasma ubi keledek. Walaupun lobak merah (karot) ialah sumber biasa untuk ß-karotena, tetapi ia tidak boleh ditanam di tanah rendah dalam iklim tropika seperti di Malaysia. Sebaliknya, ubi keledek dapat tumbuh dengan subur. Sebagai langkah menggantikan sebahagian import lobak merah dan untuk mempopularkan penggunaan ubi keledek berwarna oren untuk penghasilan produk makanan yang berkhasiat, satu program pembiakbakaan dan pemilihan untuk klon dengan kandungan ß-karotena telah dimulakan di MARDI. Satu siri uji kaji dilaksanakan untuk menilai 13 klon bersama-sama dengan dua varieti bandingan di enam lokasi, satu masing-masing di tanah bekas lombong dan tanah asid sulfat, dan dua masing-masing di tanah mineral biasa dan tanah *bris*. Analisis varians yang bergabung bagi enam lokasi menunjukkan klon Merah Manis, Tainung No. 64, Guan dan Caromex memberikan hasil ubi melebihi 15 t/ha selepas 3½–4 bulan. Purata hasil Merah Manis (26.2 t/ha) melebihi purata hasil varieti bandingan Gendut (15.8 t/ha) dengan signifikan. Caromex memberi hasil yang ketiga atau keempat tertinggi di lokasi tanah bermasalah, juga mempunyai kandungan ß-karotena (6.18 mg/100 g) yang lebih tinggi daripada kandungan varieti bandingan Kuala Bikam 2 (5.81 mg/100 g). Ujian awal yang menggunakan empat klon yang terpilih ini untuk membuat jus menunjukkan jus yang dihasilkan berpotensi dari segi rasa dan warnanya. Dengan penyelidikan yang lebih lanjut, mungkin ubi keledek berwarna oren dapat digunakan untuk menggantikan jus lobak merah. Di samping itu, tepung ubi keledek juga berpotensi untuk menggantikan tepung gandum bagi menghasilkan kek yang lebih berkhasiat.

Appendix 1. Morphological characteristics of Merah Manis

Plant organ	Character	Description
Leaf	Shoot colour	Purplish-green
	Mature colour	Green
	Leaf shape	Triangular
	Abaxial vein colour	Purplish with a purple dot at the junction of the leaf blade with the petiole
Vine	Vine colour	Green
Storage root	Shape	Oblong
	Skin colour	Light orangey-brown
	Flesh colour	Orange

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