

R6507-001

**Methods for evaluating the sensory
properties and consumer preference of
sweet potato cultivars**

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ARTI	Agricultural Research and Training Institute
DFID	Department for International Development
NRI	Natural Resources Institute
TShs (/=)	Tanzanian Shillings £1 = 1,074/= approx. US\$1 = 700/= approx.

ACKNOWLEDGEMENTS

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SUMMARY

Training in sensory evaluation and consumer preference was provided by Mr K Tomlins, NRI as part of the DFID funded project on the 'extension of storage life and improvement of quality in fresh sweet potato through selection of appropriate cultivars and handling conditions', at ARTI-Ukiriguru, Mwanza, Tanzania.

A total of four key staff received training in sensory evaluation. Subjects included:

- Introduction to sensory evaluation
- Defining the sensory problem
- Recruitment, selection and training assessors
- Basic tastes
- Odour recognition
- Sampling and presentation of the test product
- Conducting tests
- Types of panel and assessor
- Test methods; paired comparison, triangle test, ranking, descriptive profiling, consumer preference

A panel of ten Ukiriguru staff, were successfully trained to profile sweet potato cultivars and could statistically discriminate between them. In a 'mock' consumer preference study, the panel ranked five sweet potato cultivars in the same order as a panel of farmers who previously attended an extension group meeting at Ukiriguru. A method for 'calibrating' the trained panel to the consumer studies was suggested.

Staff at Ukiriguru were advised on experimental design of sensory and consumer preference trials.

I. BACKGROUND

Sweet potato is an important staple food crop in several areas of Tanzania. It is increasingly being marketed providing an important source of income for rural producers and providing an important source of food to the rapidly expanding urban population. This project (A0499) is concerned with the extension of storage life and improvement of quality in fresh sweet potato through selection of appropriate cultivars and handling conditions. Previously, this project has indicated the quality criteria considered by farmers (Kapinga *et al* 1997a) and urban consumers (Kapinga *et al* 1997b) when selecting cultivars.

On the basis of the quality criteria previously identified, there is now a need to select roots for consumption as fresh cooked roots and for simple processing. Most of the criteria identified (e.g., mealiness, good taste, appearance, low fibre) are complex and difficult to assess by scientific measurement. It is therefore proposed that the most practical method to assess new cultivars would be by a trained taste panel with consumer preference studies in the target areas. This report, involved the provision of training in sensory evaluation and consumer preference to senior staff at ARTI Ukiriguru and to assist with the experimental design of sensory and consumer studies.

II. OBJECTIVES

1. To provide training in sensory methods applicable to sweet potato cultivar selection to key staff at Ukiriguru
2. To establish a trained sensory panel at ARTI-Ukiriguru.
3. Provide training in methods for conducting consumer preference studies in rural and per-urban areas of Tanzania for cultivars of sweet potatoes.
4. Advise on the experimental design of sensory and consumer trails carried out by ARTI-Ukiriguru.

Training in sensory evaluation

The following staff received training in sensory evaluation

- Ms Elizabeth Rwiza, Field Technician, Root and Tuber Crops, Ukiriguru.
- Mrs Rahila Amour, Field Technician, Root and Tuber Crops, Ukiriguru.
- Mr Abdallah Nyango, Field Technician, Root and Tuber Crops, Ukiriguru.
- Mrs Bernadetha Mnundma, Field Technician, Root and Tuber Crops, Box 306, Tumbi, Tabora.

Training in sensory evaluation and consumer preference and based on methods given in Bainbridge *et al* 1996, comprised:

- Introduction to sensory evaluation
- Defining the sensory problem
- Recruitment, selection and training of assessors
- Basic tastes
- Odour recognition
- Sampling and presentation of the test product
- Conducting tests

- Types of panel and assessor
- Test methods; paired comparison, triangle test, ranking, descriptive profiling, consumer preference

III. ESTABLISHMENT OF A TRAINED SENSORY PANEL AT ARTI-UKIRIGURU FOR THE SENSORY EVALUATION OF SWEET POTATO CULTIVARS

Consumer preference testing of sweet potato cultivars and under varying storage conditions requires large numbers of consumers and can be costly, time consuming and only provide limited sensory information. Furthermore, the number of samples that can be evaluated in consumer trials (maximum of six) is limited. Prior testing by a trained sensory (descriptive profiling) panel would facilitate screening of experimental sweet potato cultivars under varying storage conditions and provide more detailed sensory information. The cultivars and storage conditions with the most acceptable sensory characteristics along with a preferred commercial cultivar (reference) would then be selected for consumer testing.

Preparation of sweet potato samples

The sweet potatoes were peeled and approximately 10 per cent of the root removed before each end since the texture at the ends significantly differed from the bulk of the storage root. The roots were steamed above boiling water until soft. The cooking time varied between 15 and 27 minutes.

Descriptive profiling of sweet potato cultivars

This method involves the use of graphical scales to simultaneously measure the intensity of a number of sensory attributes. Initially, the sensory attributes were determined by the panel during a group discussion where samples of the product are evaluated for appearance, odour, texture and taste. The sensory terms selected by the panel are given below:

- appearance
- external colour
- internal colour
- odour
- softness (fingers)
- taste
- chewiness
- sweetness
- mealiness
- stickiness
- fibre
- acceptability

These sensory attributes were then used to create a score sheet which used a visual method (a mark on a line) for recording their intensity (appendix 1). During each panel,

up to four test samples are randomly presented to each assessor, each labelled with a random code number. The assessor judged the intensity of each of the sensory attribute and marked it on the score sheet. A training panel, using these terms and score sheets, was used to score three sweet potato cultivars; Budagala, 440088 and B'ntvkun. An example of randomisation of the sample order and codes is given in the table 1.

Table 1: Sample randomisation and codes used for sample labelling for panel of 10 assessors and three sweet potato cultivars.

Panellist	1st sample	Code	2nd sample	Code	3rd sample	Code
1	A	527	B	796	C	680
2	A	715	C	779	B	362
3	B	694	A	659	C	196
4	B	890	C	684	A	072
5	C	228	A	458	B	385
6	C	003	B	094	A	827
7	A	786	C	050	B	243
8	B	699	A	777	C	543
9	C	089	A	278	B	925
10	B	536	C	255	A	050

where A = Budagala, B = 440088 and C = B'ntvkun

The scores for each panellist and the means for each cultivar are given appendix 2. A graphical method (spider plot) of illustrating the results was demonstrated using the Excel spreadsheet; this clearly highlighted sensory differences between the three cultivars (figure 1).

One way analysis of variance (ANOVA) indicated that the panel could significantly ($P=0.05$) distinguish the three cultivars for seven of the twelve sensory attributes. It is expected that replication of the samples and further experience gained by the assessors will increase the number of terms that significantly distinguish the sweet potato cultivars.

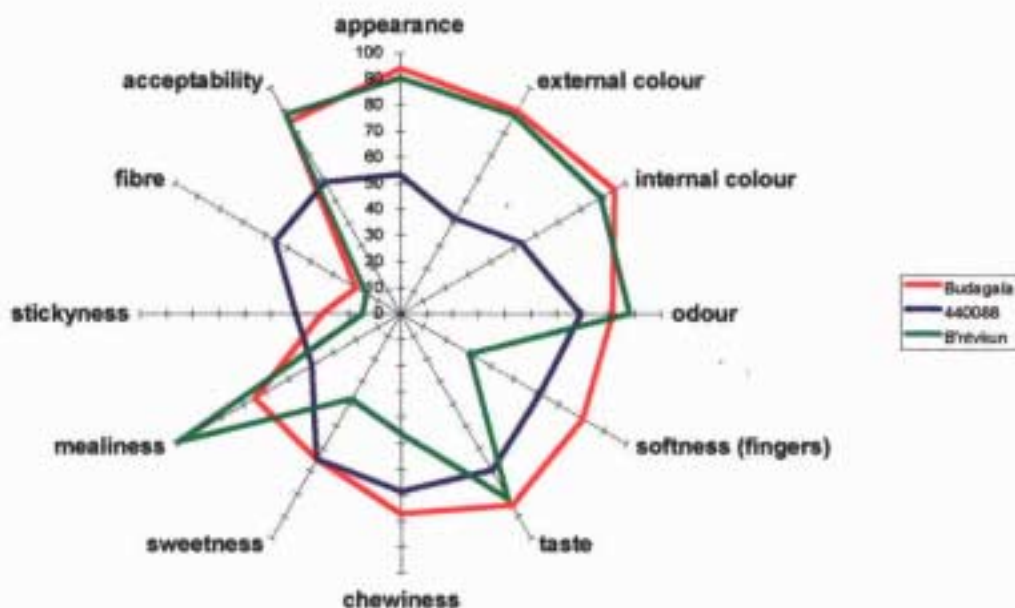
IV. CONSUMER PREFERENCE

Food acceptability is often referred to as liking, preference, enjoyment, selection and consumption of a food or drink. Consumer acceptability actually represents different forms of behaviour to food products. It is vital that the objectives of any consumer study are clearly defined in advance, and the experimental design and questionnaires are carefully designed. For example, 'how much do you like' and 'how much do you eat' are not the same because consumption is influenced not only by sensory preference, but among other considerations, price and availability.

For consumer preference trials of sweet potato cultivars and varying storage conditions carried out in villages and peri-urban sectors, it is recommended that the maximum number of samples compared is six and that the ranking method is used (part 4, Bainbridge *et al* 1996). At least 100 consumers should be interviewed to ensure

statistically representative sampling. Consumers must be representative of the age, sex and socio-economic groups in each village or peri-urban sector.

Figure 1: Spider chart of mean sensory scores for three sweet potato cultivars.



Test samples must be prepared as carefully and accurately as for the trained sensory panels at Ukiriguru. It is suggested that for each consumer, the sample order is randomised and each sample coded with random numbers (appendix 3). Each consumer interviewed should be invited to rank the sweet potato cultivars in order of preference which should be recorded on the report sheet detailed in appendix 4. A follow up interview can provide an insight into factors which affect their preference and purchasing decisions. These may include:

- Age category (10 to 19, 20 to 29, 30 to 39, 40 to 49, 50 to 60, over 60)
- Sex category (male, female).
- which sample was the most preferred and why.
- which sample was the most disliked and why.
- how often do they consume sweet potatoes (once at day, 3 - 5 times a week, 1 - 2 times a week, less than once a week, never).
- where do they consume sweet potato.
- who purchases the ingredients.
- who prepares it.
- Are sweet potatoes mixed with other ingredients
- what ingredients are usually included in the sweet potato.
- do they consume other sweet potato products.
- how much do they spend on sweet potatoes each month.

Questions asked by the interviewer must be easy to understand with minimal possibility of misinterpretation. Questions must be clear and easily understood by the consumer. Open ended questions should be avoided but the facility for recording spontaneous comments should be retained.

Analysis of the results

The ranking method in part 4 of the quality manual for non-grain starch staples (Bainbridge *et al* 1996) should be used for guidance. The results of a ranking test of five sweet potato cultivars carried out during this visit and a worked example are given in appendix 5. The results indicated that the panel ranked the cultivars in the same order as farmers who had attended an earlier extension meeting..

V. SUGGESTIONS ON THE EXPERIMENTAL DESIGN OF SENSORY AND CONSUMER TRIALS

The following trials were discussed:

- Comparison of the trained panel at Ukiriguru with consumer preference in the villages for 4 to 5 cultivars at three locations
- Evaluation of nine sweet potato cultivars in the Uniform Yield Trial (UYT) along with three commercially acceptable cultivars using the trained panel

Comparison of trained and consumer preference panels

At each of three locations, a total of four to five sweet potato cultivars (including a known commercial cultivar well liked at that location) of differing sensory properties will be assessed by approximately 100 consumers in the villages. The same samples will also be scored by the trained panel at Ukiriguru. Suggested random orders of the sweet potato samples presented to the consumers along with random code numbers are given in appendix 3. A form for recording the villagers preferences is given in appendix 4.

Analysis of the consumer preference test is by the Friedman method. The scores obtained by the trained panel can be statistically analysed by both the Friedman method and ANOVA. The use of ranks will enable both the trained and consumer panels to be compared. The spider plot, is a useful method for comparing the sensory characteristics of the cultivars as obtained by the trained panel.

This study may answer the following questions:

- Can the consumers differentiate between the cultivars?
- Can the trained panel differentiate between the cultivars and by which sensory attributes?
- Can we use the trained panel to predict the outcome of the consumer panel and hence use this to rapidly screen new cultivars and storage conditions?
- Does the consumer preference differ from location to location?

Uniform yield trial

A total of nine sweet potato cultivars and three commercial cultivars well liked by consumers will be scored in duplicate by the trained panel to map their sensory profiles. An experimental design is suggested in appendix 6. This study may help to answer the following questions:

- Can the trained panel differentiate between the sweet potato cultivars?
- Which sweet potato cultivars are likely to be less acceptable than the commercial cultivars?
- Which are equally acceptable?
- Which are more acceptable?
- Which sensory attributes are most suited for significantly distinguishing between the cultivars?

VI. SUMMARY OF RECOMMENDATIONS

Immediately following this visit, a team from Ukiriguru were to carry out the following programme of work funded through project A0499 (**action: Dr R Kapinga, Ukiriguru**).

1. Complete the descriptive sensory profiling using the trained panel of 12 cultivars presently being assessed within the breeding programme.
2. Carry out consumer preference tests of 4-5 cultivars presently available in the markets in each of three locations (Mwanza, Meatu, Ukerewe).
3. Carry out descriptive sensory profiling using the trained panel of the same cultivars as assessed in 2.

Mr K Tomlins will assist the Roots and Tuber Program, Ukiriguru in the analysis of the results from this work (**action: Dr R Kapinga to forward results**)

REFERENCES

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Appendix 1: Score sheet for sensory evaluation of sweet potato

JINA _____

TAREHE _____

NAMBA YA SAMPULI _____

Chunguza hizo sampuli zilizopo mbele yako. Onyesha na uamue uwingi wa sifa zilizoonyeshwa kwenye mistari iliyopo hapo chini. Weka alama ya mistari uliosimama sehemu unayoona inafaa katika sifa hiyo.

Kinavyoonekana	mbaya	_____	nzuri
Rangi (nje)	mbaya	_____	nzuri
Rangi (ndani)	mbaya	_____	nzuri
Harufu	mbaya	_____	nzuri
Ulaini mkononi	kigumu	_____	laini
Ladha	mbaya	_____	nzuri
Utafunaji	kigumu	_____	laini
Sukari	kidogo	_____	nyingi
Wanga	kidogo	_____	mwingi
Kunata	hakinati	_____	kinanata
Nyuzi	hakina	_____	kina nyuzi sana
Kukubalika	hakikubaliki	_____	kinakubalika

Rangi _____

Appendix 2: Scores and mean scores for profiling of three sweet potato cultivars.

Scores given by each panellist for three sweet potato cultivars.

Name	Cultivar	appearance	external colour	internal colour	odour	softness (fingers)	taste	chewiness	sweetness	mealiness	stickyness	fibre	acceptability
Mkiramwinyi	A	112	113	112	85	111	100	105	93	74	8	1	98
Pendo	A	104	105	104	90	90	105	109	112	46	3	56	98
Shuhudia	A	104	104	103	64	61	104	60	10	20	13	15	101
Godwin	A	58	54	63	57	57	27	24	24	53	52	3	29
Mohamed	A	107	108	108	109	23	108	108	107	107	95	95	107
Ruzzo	A	90	86	77	60	75	89	50	7	31	1	1	67
Mwalukasa	A	79	65	81	68	92	79	83	51	73	27	1	95
Herman	A	109	108	111	111	99	110	98	89	105	20	7	112
Rugutu	A	66	49	92	100	89	48	28	48	87	20	13	51
Kemi	A	109	107	100	73	112	81	107	107	52	65	5	89
Mkiramwinyi	B	67	37	36	52	2	44	6	110	57	69	0	41
Pendo	B	55	62	77	73	90	105	88	106	59	14	71	57
Shuhudia	B	75	57	78	97	104	56	108	65	37	14	60	47
Godwin	B	39	36	37	35	22	51	51	77	6	18	2	63
Mohamed	B	82	77	78	78	108	108	108	7	25	58	78	90
Ruzzo	B	14	10	17	22	8	6	75	5	6	82	100	12
Mwalukasa	B	23	27	32	26	43	31	59	35	3	18	108	5
Herman	B	56	24	45	108	87	86	97	56	74	19	53	84
Rugutu	B	16	7	33	107	53	107	24	83	83	17	8	98
Kemi	B	105	82	103	95	101	106	70	104	44	92	76	82
Mkiramwinyi	C	104	96	103	112	4	112	14	51	113	0	0	110
Pendo	C	97	104	104	102	58	56	43	60	91	9	11	109
Shuhudia	C	109	106	54	103	11	60	105	59	104	12	13	101
Godwin	C	66	72	81	92	22	82	17	8	95	1	7	61
Mohamed	C	107	106	105	106	7	106	32	10	91	92	93	105
Ruzzo	C	66	72	81	92	22	82	17	8	95	1	7	61
Mwalukasa	C	77	69	95	46	18	60	30	26	102	8	4	58
Herman	C	110	109	108	109	98	109	107	71	79	8	2	111
Rugutu	C	102	86	104	52	38	82	49	59	110	14	11	98
Kemi	C	62	56	55	68	31	76	49	27	110	2	2	65

Mean scores for three sweet potato cultivars.

Data	Cultivar		
	Budagala	440088	B'ntvkun
appearance	94	53	90
external colour	90	42	88
internal colour	95	54	89
odour	82	69	88
softness (fingers)	81	62	31
taste	85	70	83
chewiness	77	69	46
sweetness	65	65	38
mealiness	65	39	99
stickiness	30	40	15
fibre	20	56	15
acceptability	85	58	88

Appendix 3: Random sample order and random number codes

No	Sample order											
	1st		2nd		3rd		4th		5th		6th	
	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code
1	2	58	6	77	3	51	1	72	5	27	4	98
2	1	24	3	99	6	48	4	25	2	43	5	54
3	1	61	3	4	5	12	6	34	4	80	2	81
4	6	1	3	24	4	12	1	62	2	17	5	31
5	2	13	5	97	1	18	6	91	4	2	3	72
6	2	38	3	23	5	15	4	37	1	71	6	32
7	5	70	4	19	3	72	6	4	1	65	2	70
8	6	9	4	8	2	82	3	29	1	82	5	61
9	4	51	6	99	5	33	1	35	2	82	3	10
10	3	31	6	77	5	80	2	99	1	18	4	17
11	4	67	2	82	1	21	6	86	5	91	3	6
12	4	19	3	45	6	12	5	46	1	37	2	53
13	6	87	5	41	3	85	1	54	2	81	4	17
14	5	67	1	47	6	54	4	46	2	35	3	62
15	4	79	1	14	6	37	2	72	5	65	3	29
16	6	74	1	82	2	87	5	19	4	21	3	2
17	2	90	5	11	3	20	1	39	6	83	4	65
18	6	85	1	62	2	10	4	80	3	91	5	64
19	2	35	5	48	3	75	4	89	6	50	1	26
20	2	50	5	17	1	93	3	47	4	77	6	18
21	1	57	6	24	3	3	2	84	5	58	4	55
22	3	48	5	29	2	85	4	99	1	10	6	3
23	4	2	2	22	5	50	3	45	6	62	1	84
24	6	59	2	64	5	59	4	71	3	56	1	30
25	6	60	2	62	5	52	4	74	1	43	3	75
26	4	59	1	84	2	30	3	55	5	94	6	44
27	2	45	3	59	4	69	5	26	1	53	6	49
28	6	5	4	24	5	20	3	75	2	68	1	45
29	2	4	4	71	3	63	5	75	6	43	1	72
30	5	84	4	49	6	89	2	73	1	65	3	42
31	5	83	1	71	2	51	4	97	3	52	6	29
32	4	80	6	86	2	14	5	22	1	32	3	47
33	1	76	2	37	6	49	5	58	3	38	4	71

34	4	71	2	85	6	72	1	54	3	16	5	36
35	3	86	2	98	4	16	5	2	6	9	1	41
36	6	24	3	26	1	52	2	25	5	73	4	3
37	3	63	5	62	4	94	2	27	1	97	6	26
38	3	60	5	54	4	18	2	50	1	46	6	95
39	3	4	4	70	6	41	1	66	2	28	5	31
40	4	19	1	12	3	21	5	30	2	10	6	47
41	6	79	1	61	3	77	2	36	4	19	5	42
42	5	63	4	35	3	91	1	22	2	73	6	99
43	1	1	2	45	6	42	5	97	3	56	4	92
44	6	63	1	68	3	15	2	66	4	18	5	18
45	1	7	5	33	4	78	2	9	3	79	6	84
46	3	76	4	53	1	28	2	22	5	45	6	13
47	3	75	1	55	6	33	4	7	5	37	2	84
48	6	17	2	93	5	37	1	76	3	67	4	70
49	2	8	3	85	4	66	5	34	6	22	1	31
50	4	21	2	92	6	42	5	23	1	24	3	16
51	4	56	2	80	1	69	6	6	3	62	5	55
52	4	35	2	23	3	82	6	38	5	84	1	35
53	1	98	3	64	4	90	2	72	5	97	6	30
54	3	77	4	41	5	68	6	11	1	35	2	6
55	3	27	6	7	2	18	4	69	1	83	5	44
56	3	44	5	28	1	6	2	22	4	42	6	58
57	3	82	1	39	2	65	5	85	4	34	6	94
58	3	67	5	84	1	24	2	54	6	69	4	92
59	5	62	6	9	1	99	4	62	2	5	3	2
60	4	38	1	4	6	97	2	13	5	29	3	43
61	1	34	6	63	2	15	4	30	3	54	5	2
62	5	15	4	34	2	83	1	87	6	50	3	20
63	3	53	6	60	5	32	1	33	2	76	4	58
64	2	74	3	6	6	17	1	5	5	86	4	97
65	5	75	1	67	4	4	2	52	3	74	6	54
66	5	9	2	74	3	54	1	42	4	82	6	7
67	1	71	6	57	4	54	5	87	3	74	2	77
68	6	97	5	57	4	66	1	13	2	75	3	46
69	3	98	1	95	6	17	2	24	4	49	5	14
70	6	44	4	69	5	86	2	9	3	79	1	98
71	6	22	2	42	4	38	5	1	3	52	1	7
72	2	8	5	4	6	33	4	21	3	38	1	43

73	3	31	1	44	2	57	6	24	4	81	5	9
74	2	17	4	75	6	87	3	24	5	73	1	39
75	3	25	4	81	2	98	6	11	1	67	5	75
76	1	50	3	79	2	60	4	12	6	4	5	68
77	3	17	2	79	1	66	5	98	4	34	6	21
78	2	70	4	24	3	41	1	39	6	14	5	31
79	5	26	3	67	4	41	6	5	1	4	2	51
80	5	77	4	30	6	49	3	94	1	2	2	97
81	5	9	4	10	6	22	1	98	3	76	2	89
82	2	19	3	33	4	84	5	98	6	42	1	10
83	4	80	5	98	2	59	1	87	6	77	3	99
84	5	42	3	39	6	64	2	77	1	4	4	52
85	3	62	5	73	2	44	6	65	1	76	4	83
86	6	64	2	88	5	44	1	63	3	88	4	12
87	2	19	4	62	5	25	3	75	6	36	1	26
88	2	30	5	53	4	80	1	22	3	97	6	85
89	6	46	5	27	1	96	3	41	4	58	2	18
90	6	46	1	98	4	27	3	21	5	66	2	15
91	4	1	5	49	3	62	6	99	1	83	2	89
92	1	33	2	1	6	23	5	95	4	36	3	63
93	4	37	2	27	3	35	1	36	6	91	5	59
94	4	67	2	37	3	36	1	71	6	47	5	1
95	6	12	1	81	3	73	2	50	5	83	4	18
96	3	8	5	86	4	32	2	86	6	7	1	54
97	3	42	2	51	6	58	4	44	5	81	1	55
98	3	37	1	99	5	87	2	40	6	90	4	43
99	6	76	5	63	1	97	3	38	4	94	2	87
100	3	43	2	53	6	44	4	76	5	64	1	91

Appendix 4: Example score sheet for consumer ranking of six sweet potato samples

Consumer testing score sheet

Date:

Name	Order of preference of test samples						
	No.	1st	2nd	3rd	4th	5th	6th
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
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Appendix 5: Ranking method in consumer testing

Ranking is a test in which a series of three or more samples are presented to an assessor or consumer at the same time and which are to be arranged in order of intensity, degree or preference. The simplicity of the method makes it valuable in consumer testing.

Before starting the test, it is important to ensure the consumer understands it is a preference test and that the samples must be ranked.

Analysis and interpretation of the results

Calculation of the rank sums

Decode the samples and tabulate the rank orders to each sample given by each assessor. Calculate the rank sum for each sample by summing the ranks for each assessor.

By comparing the rank sums for the samples, it is possible to obtain an evaluation of the differences between the samples.

Statistical interpretation

Friedman test: This test is used where the order of the rankings is not predetermined, for example in consumer preference tests (BS 5929, ISO 8587).

The Friedman value (F) can be calculated as follows:

$$F = \frac{12}{JP(P+1)} (R_1^2 + R_2^2 + \dots + R_p^2) - 3J(P+1)$$

Where: J = number of assessors
 P = number of samples (or products)
 R₁, R₂...R_p = rank sums attributed to the P samples for the J assessors

The value F is then compared with the critical values from the Friedman test (table 4) when the number of assessors is between 2 and 15 and the chi-squared distribution (table 5) when the number of assessors exceeds 15. If F is equal to or greater than the critical value corresponding to the number of samples and the selected level of significance (P=0.05, 0.01), it can be concluded that there is a significant overall difference between the samples.

Where an overall difference between the samples has been statistically demonstrated, the rank sums of each sample can be used to identify significant differences for the sample pairs.

Let i and j be two samples and R_i and R_j their rank sums. Two samples are different if:

$$|R_i - R_j| > 1.960 \sqrt{\frac{JP(P+1)}{6}} \quad (0.05 \text{ significance level})$$

$$|R_i - R_j| > 2.576 \sqrt{\frac{JP(P+1)}{6}} \quad (0.01 \text{ significance level})$$

Note: This test provides an indication of the order in which the samples are hierarchically ranked. However, the risk of an incorrect conclusion increases rapidly when these tests are carried out simultaneously.

Table 4: Approximate values from the Friedmans test

Number of assessors J	Number of samples P					
	3	4	5	3	4	5
	Significance (P = 0.05)			Significance (P = 0.01)		
2	-	6.00	7.60	-	-	8.00
3	6.00	7.00	8.85	-	8.20	10.13
4	6.50	7.50	8.80	8.00	9.30	11.00
5	6.40	7.80	8.96	8.40	9.96	11.52
6	6.33	7.60	9.49	9.00	10.20	13.38
7	6.99	7.62	9.49	8.85	10.37	13.38
8	6.25	7.65	9.49	9.00	10.35	13.28
9	6.22	7.81	9.49	8.66	10.34	13.28
10	6.20	7.81	9.49	8.60	10.34	12.28
11	6.54	7.81	9.49	8.90	10.34	12.28
12	6.16	7.81	9.49	8.66	10.34	12.28
13	6.00	7.81	9.49	8.76	10.34	12.28
14	6.14	7.81	9.49	9.00	10.34	12.28
15	6.40	7.81	9.49	8.93	10.34	12.28

Table 5: Critical values of the Chi-squared distribution

Number of samples or products	Number of degrees of freedom ($\nu = P - 1$)	Level of significance	
		0.05	0.01
3	2	5.99	9.21
4	3	7.81	11.34
5	4	9.49	13.28
6	5	11.07	15.09
7	6	12.59	16.81
8	7	14.07	18.47
9	8	15.51	20.09
10	9	16.92	21.67
11	10	18.31	23.21
12	11	19.67	24.72
13	12	21.03	26.22
14	13	22.36	27.69
15	14	23.68	29.14

Example calculation for 5 sweet potato cultivars

Ranks for each cultivar

Assessor	SP93/34	SPN/0	IBOJA	SP93/2	Sinia A
1	5	1	3	4	2
2	4	1	5	3	2
3	5	1	4	2	3
4	4	2	5	3	1
5	5	4	2	1	3
6	4	1	5	3	2
7	5	1	3	4	2
8	5	1	3	4	2
9	3	2	5	1	4
10	4	2	3	5	1
Rank sum	44	16	38	30	22

From the ranks the most preferred cultivars was SPN/0, then Sinia A, SP93/2, Iboja and lastly SP93/34.

Calculation

$$F = \frac{12}{12 \times 5 (5 + 1)} (44^2 + 16^2 + 38^2 + 30^2 + 22^2) - 3 \times 10 (5+1)$$

$$F = \frac{12}{300} (5,020) - 180$$

$$F = 20.8$$

Since the critical value for 6 samples are 9.49 ($P = 0.05$) and 12.28 ($P = 0.01$), we can conclude that the preference of the sweet potato cultivars differ at the 95% and 99% significance level..

Two samples differ if $|R_i - R_j|$ is greater than 13.9 ($P = 0.05$) and 18.2 ($P = 0.01$). The difference are given in table 6.

Table 6: Differences in rank sums

	Sinia A	SP93/2	IBOJA	SP93/34
SPN/0	6	14	22	28
Sinia A		8	16	22
SP93/2			8	14
IBOJA				6

We can conclude:

- SPN/0 and Sinia A were the most preferred
- Iboja and SP93/34 were the least preferred
- SPN/0 and Sinia A were preferred to Iboja and SP93/34
- SP93/2 was preferred to SP93/34

Appendix 6: Experimental design for UYT experiment

Treatments

Number of sweet potato cultivars = 12

Replication = 2

Number of assessors = 10

Number of sample presented to each assessor at each panel = 4

Number of panels = 6

Panel	Assessor																			
	A		B		C		D		E		F		G		H		I		J	
	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code	Sample	Code
1	1	237	4	140	8	447	2	897	4	843	12	744	5	458	5	580	3	982	8	73
	11	874	9	170	7	791	5	749	11	5	6	311	9	645	8	838	2	466	11	658
	5	420	10	323	11	902	12	177	5	965	7	151	1	414	4	286	12	587	7	8
	6	987	12	896	3	783	4	617	6	196	1	13	7	908	7	576	1	332	12	888
2	3	245	5	702	9	29	10	591	11	745	4	487	9	483	2	433	4	813	2	287
	4	369	8	697	4	201	8	946	9	745	12	66	6	133	4	709	8	109	5	684
	5	2	2	268	2	238	5	332	2	475	4	809	2	64	1	211	6	561	3	298
	9	831	9	470	1	382	2	391	12	709	11	266	1	941	8	244	2	404	1	343
3	7	128	11	921	6	400	3	318	4	700	2	96	12	159	7	282	11	47	9	655
	3	828	1	106	5	24	9	406	10	38	7	940	8	998	10	833	7	817	4	687
	12	697	12	126	12	55	6	846	1	200	10	767	7	465	12	340	10	989	1	976
	9	270	4	430	10	951	7	457	6	257	8	794	2	106	11	416	5	528	10	935
4	1	819	3	854	7	801	11	4	5	700	3	556	11	288	5	853	6	125	12	918
	10	652	7	679	3	932	7	590	2	759	11	755	4	587	9	765	9	22	5	754
	4	838	6	398	9	820	8	747	3	549	2	131	8	539	6	570	11	495	9	53
	2	128	8	184	12	765	9	803	7	652	1	352	6	856	2	501	7	641	4	4
5	8	484	1	292	1	687	4	713	10	878	5	786	3	867	9	654	5	839	6	947
	6	50	11	973	11	98	11	989	9	909	10	722	5	80	1	741	9	274	3	811
	10	734	5	307	4	314	12	101	1	203	6	68	10	344	3	451	4	607	2	51
	11	827	10	262	5	197	1	45	8	410	3	212	11	545	10	97	8	209	8	898
6	12	281	6	714	10	148	3	284	7	265	9	224	3	102	3	325	3	933	10	121
	8	676	2	694	6	999	6	108	12	393	5	791	10	955	12	793	1	758	7	266
	2	147	7	814	8	520	10	504	8	878	8	935	4	639	6	481	12	593	6	10
	7	184	3	929	2	830	1	858	3	590	9	883	12	446	11	678	10	381	11	490