Nutrition and ecosystems in Sarawak: The role of the areca nut

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The effects of population pressure on agricultural sustainability in the delicate tropical and subtropical ecosystems have often been thought to explain high prevalence rates of malnutrition in rural South-East Asia. However, recent studies in rural Sarawak suggest that processes of modernisation have resulted in increased variations in energy nutritional status in adults. A contributory factor may be consumption of the areca nut (Malay *pinang*, of the palm *Areca catechu*). This is thought to influence energy balance through effects on appetite and resting metabolic rate. Body mass index (BMI, kg/m^2) data for 325 Iban men and 438 non-pregnant Iban women, measured in 1990 and again in 1996, have been analysed in relation to areca use, smoking behaviour, socio-economic status, and reported morbidity. Body composition derived from skinfold thickness measurements for 313 men and 382 women was also analysed. The results suggest that use of areca nut is associated with significantly lower age-related increments in BMI and percentage body fat in women after allowing for age, smoking, reported morbidity, and confounding socio-economic factors. Therefore, the impact of recent economic and social development seen in rising prevalences of 'over-nutrition' may be modulated by use of the areca nut.

Key words: areca nut, tobacco, body mass index, body fatness, ageing, appetite, 5-HT, Sarawak, Malaysia.

Introduction

Rural populations in tropical and subtropical Asia have in the past been thought to experience levels of malnutrition which increase approximately in proportion to their density.[1–3] Empirical evidence for this phenomenon is, however, remarkably weak.[4] Moreover, recent trends in the Asia–Pacific region indicate the emergence of 'diseases of affluence', associated with obesity, to a greater extent than those of chronic undernutrition.[5,6] For example, there is much evidence for this from Malaysia,[7] China,[8] Samoa,[9] and to a variable extent in Papua New Guinea.[10] Underlying these phenomena are changing dietary patterns,[11] lower physical activity levels associated with altered occupational structures,[9] and varying trends in obesity-related fertility rates.[12]

Increases in tobacco smoking and associated cancer incidence rates have also characterised recent economic development in Asia.[6] Less attention has been given to changing prevalences of smokeless tobacco use, which is widespread and appears to account for a comparatively high incidence of oral cancer.[13] In India, smokeless tobacco has been aggressively promoted through brand advertising associated with commercial marketing of areca nut preparations or *pān*.[14] The evidence that areca nut preparations without tobacco are carcinogenic to humans has been described as 'inadequate'.[15] In Papua New Guinea, the associated topical application of slaked lime (calcium hydroxide, $Ca(OH)_2$) to the buccal mucosa may be carcinogenic.[16] However, this practice appears unique to Melanesia.[15]

Although tobacco is generally accepted to be a source of carcinogenic and other risk factors for poor health, it is also well established that tobacco smoking may contribute to body weight regulation through effects on appetite and energy expenditure.[17,18] The extent to which tobacco use has lessened the development and spread of obesity in Asia is unclear. However, anecdotal evidence suggests that use of the areca nut may moderate appetite, and therefore influence body weight and fatness in Asia.

There is as yet no quantitative evidence for such effects of areca chewing. However, the wider literature on populations exposed to periodic food shortages contains numerous generalisations about the use of the areca nut to suppress hunger,[15,19–23] or remarks upon its use in this context.[24] In this respect, the use of the areca nut quid can be compared to tobacco smoking,[25] and perhaps also to the chewing of coca leaves in South America.[26,27] Extensive studies of the cultural history of areca use by Gode[28] do not report such hunger-suppressing properties, perhaps because the historical and textual evidence primarily concerns wealthier social groups who would not have been subject to intermittent food shortage. There is considerable regional variation in the composition of the quid, for example within India.[14] Relatively affluent people could have indulged in a remarkable range of concoctions of areca nut, including the nut being boiled in milk with the addition of aromatic preparations, seeds, and leaves of *Cannabis sativa*;[29] or mixed with other substances including cloves, camphor, herbal medicines, gold dust, and what are purported to be aphrodisiacs.[14]

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In addition to possible carcinogenicity, a wide range of other properties, many positively valued, have been attributed to the areca nut itself or to the quid. These include the capacity to induce euphoria;[30] provoke bronchospasm in asthmatics;[31] stimulate salivation[32] or reduce it;[33] increase heat loss by vasodilatation;[34] enhance the motor response;[35] strengthen the gums and sweeten the breath;[29] reduce risk of dental caries;[19] enhance serial learning;[36] control diarrhoea and vomiting;[37] and remove intestinal helminths,[29] with possible impact on iron status during pregnancy.[38] The areca nut has also been considered to be a goitrogen[39] and to play a mutagenic role in aetiology of diabetes.[40]

Many of these attributed effects remain to be established empirically. Against this background, our paper reports a study intended to test the hypothesis that areca chewing is associated with a reduced age-related increment in body weight and fatness in a rapidly modernising population of rural Sarawaki adults.

Methods

In 1990, a harvest season anthropometric survey was undertaken on 1047 adults in Song and Kanowit Districts of Sarawak. Results of this study have been reported elsewhere.[4,41] In 1996, two rounds of follow-up visits were undertaken, treating the 1990 data as a baseline. Applying the same anthropometric methods as in 1990, measurements were made of standing height to the nearest 0.1 cm using a rigid CMS anthropometer; weight, lightly clothed, to 100 g using digital Soehnle scales; and skinfold thicknesses to 0.1 mm at the biceps, triceps, subscapular, and suprailiac sites using Holtain calipers. Measurements were made by two workers in 1990 and a third in 1996, and were corrected for interobserver error before analysis. The $\log_{10}$ of the sum of four skinfold thicknesses was then used to derive percentage body fat by the age- and sex-specific equations of Durnin and Womersley[42] and the formula of Siri.[43] Compared to bioelectrical impedance analysis, this method has been found to underestimate body fat mass significantly by 1.5–2.5 kg in Indonesian women, but not in men.[44]

More recently, stronger correlations between skinfold thicknesses and body fat mass and percentage body fat determined by D_2O have been reported for rural Sarawaki women than for men from the same area as that of the present study. However, correlations with the body mass index (BMI) were equally strong in both sexes.[45] The sex difference may in part result from the greater range of variation in body fatness and fat content of women than men, and suggests that the body composition estimates presented for females in this paper may be more robust than those for males.

After accounting for deaths (84), untraced individuals (58), non-compliance (8), pregnancies in both years (48), recording errors or omissions (54), and data ‘cleaning’ (32), there remained 325 men and 438 women with anthropometric data for analysis of body mass index. After allowing for unpalpable skinfold thicknesses, there remained 313 men and 382 women with data for analysis of body fatness. In most cases measurements were made twice in 1996 and have been averaged across the two rounds of the survey as there was little evidence of seasonality. In other cases, single first round measurements have been used in analysis; in an isolated instance, a single second round set of measurements on a 32-year-old male has been included.

Household-level interviews were used in 1996 to establish presence or absence of glass windows, piped water in the home, lavatory or latrine, and electricity. The sum of items present (0–4) was used as a hygiene quality score. In subsequent analysis this was reduced to two categories defined by values < 3 and ≥ 3. As inquiries about cash savings were sensitive, and the answers of questionable reliability, the two hygiene categories have been treated as a proxy for socioeconomic status.

Morbidity status was assessed by interview at the time of anthropometric measurements using a two-week recall period together with a symptom check-list covering acute and chronic conditions. These symptoms included cough, fever, diarrhoea, epigastric pain, and chest pain, but analysis has excluded those associated with hypertension. In the analysis presented here, the 2-week morbidity pattern for the first 1996 round is used; use of both rounds of reported morbidity in analysis did not alter the findings significantly. Also recorded at this interview were the reported frequency of tobacco smoking, alcohol drinking, and areca nut chewing. Pattern of use of the areca nut was classified as either consisting of the nut alone, or the nut within a quid (the *ilum*), consisting of pepper leaf, slaked lime, sometimes with the *gambir* leaf, with or without tobacco. In analysis, the data have been disaggregated by frequency of use (occasional, daily); and the daily users have been distinguished by whether they usually took the nut alone or consumed it in a quid (whether with tobacco, approximately 80% of all daily quid users, or without). In regression analysis, dummy variables have been used to represent these three categories of areca user.

It was rarely possible to elicit from recall a definite age at inception of areca use, but there was a tendency for both men and women to report starting in young adulthood, particularly in association with pregnancy and childbirth. Questions about areca use were not asked in 1990; and it has therefore been assumed that most of those reporting use in 1996 had taken up areca chewing before 1990. All interviews were conducted in the vernacular Iban language by a trained nurse or field assistant together with the authors.

Measurements of fasting resting metabolic rate (RMR) were undertaken in 1990 on a subsample stratified by body mass index.[46] In 1996, measurements of fasting RMR were again undertaken, this time on a subsample stratified by smoker/nonsmoker and areca user/non-user status; these have been reported elsewhere.[33]

Statistical analysis used SPSS/PC 4.0 to apply χ^2 tests, analysis of variance, analysis of covariance, and multiple regression methods with the level of statistical significance set at $P < 0.05$.

Results

Table 1 shows the summary physical characteristics of the men and women in 1990 and 1996. Over the six year interval there was a slight increase in mean and variance of body weight and BMI in both sexes, but more prominently among women. The change in body composition indicates a decline in fat-free mass coupled with an increase in fat mass, result-

Table 1. Summary physical characteristics and body composition of subjects

	Men n = 325		Women n = 438	
	Mean	SD	Mean	SD
Age 1996	50.1	15.4	48.3	14.0
Weight 1990 (kg)	51.5	6.7	47.5	8.9
Weight 1996 (kg)	51.6	8.4	48.5	10.7
Height 1996 (cm)	157.0	5.6	147.3	5.0
BMI 1990 (kg/m^2)	20.7	2.2	21.7	3.6
BMI 1996 (kg/m^2)	20.9	2.8	22.2	4.3
	n = 313		n = 382	
	Mean	SD	Mean	SD
Fat-free mass (kg) 1990	43.0	5.1	32.3	4.4
Fat-free mass (kg) 1996	40.8	5.1	30.7	4.3
Fat mass (kg) 1990	8.4	3.1	14.0	4.5
Fat mass (kg) 1996	10.0	3.9	16.1	5.7
Percentage fat 1990	16.2	4.4	29.8	5.3
Percentage fat 1996	19.3	5.3	33.5	6.2

BMI, body mass index.

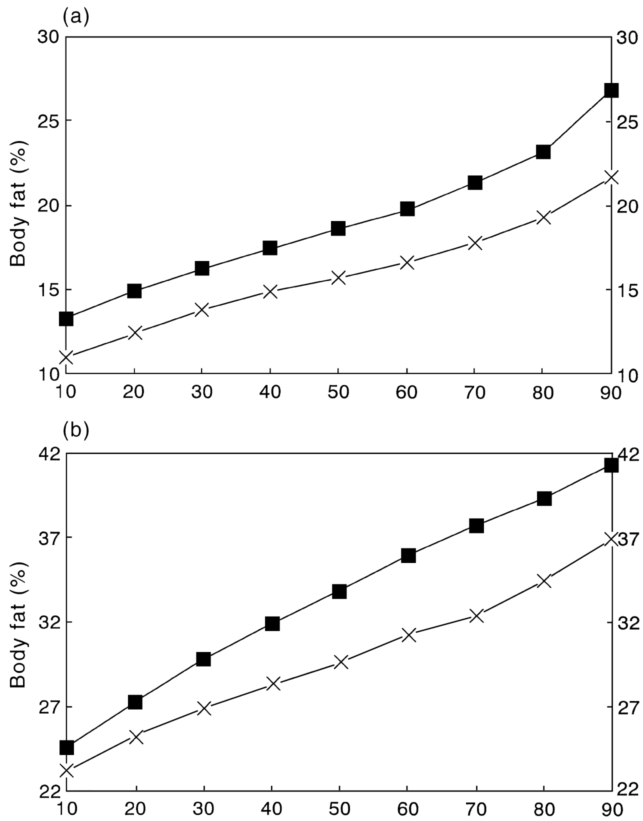

Figure 1. Deciles of percentage body fat in 1990 and 1996 in (a) 313 Iban men and (b) 382 Iban women. (×), % fat 1990; (■), % fat 1996

ing in a net increase in mean percentage body fat of about 3–4% in each sex.

Figure 1 shows deciles of the distribution of percentage body fat for each sex and survey year, indicating that increased fatness characterises the whole range of the population. This increase was approximately equally distributed across deciles in men, with little evidence of skew. However, in women the two curves begin in parallel but diverge from the twentieth percentile, suggesting a marked skew in which a greater increment in fatness has occurred in the fatter majority of this group than at the lower end of the distribution.

Table 2. Interaction of smoking, drinking, and areca chewing: Percentage frequencies in 325 Iban men and 438 Iban women

	Non-smokers	Smokers	Total	χ^2
Areca nut				
Men				
Non-users	29.2	45.5	74.8	
Users	9.8	15.4	25.2	
Total	39.1	60.9	100	0.00, ns
Women				
Non-users	32.4	6.4	38.8	
Users	48.2	13.0	61.2	
Total	80.6	19.4	100	1.24, ns
	Non-drinkers	Drinkers	Total	
Areca nut				
Men				
Non-users	19.1	55.7	74.8	
Users	5.8	19.4	25.2	
Total	24.9	75.1	100	0.18, ns
Women				
Non-users	24.7	14.2	38.8	
Users	31.3	29.9	61.2	
Total	55.9	44.1	100	6.01, $P < 0.05$
Men				
Non-smokers	14.8	24.3	39.1	
Smokers	10.2	50.8	60.9	
Total	24.9	75.1	100	17.3, $P < 0.0001$
Women				
Non-smokers	44.7	35.8	80.6	
Smokers	11.2	8.2	19.4	
Total	55.9	44.1	100	0.05, ns

ns, not significant.

There was no interaction between areca use and smoking in either sex. However, men tended to smoke (60.9%) rather than to use the areca nut (25.2%), while women showed the converse preference for areca nut (61.2%), rather than smoking (19.4%). Table 2 shows the frequency distribution of reported usage, indicating that the pattern of alcohol use tended to follow the smoking or areca use preference of each sex. For these reasons, anthropometric data have been analysed separately for each sex.

The pattern of areca use varied with age similarly in both sexes, suggesting a tendency for occasional usage at a younger age to develop with time into a daily habit and to culminate in daily consumption of the whole quid (Table 3). Table 3 also shows analysis of BMI in 1996 and percentage change in BMI across the follow-up period according to areca use category, allowing for linear effects of age. These findings suggest no significant variation with usage by men. However, the findings for women point to a moderately significant trend in declining percentage change in BMI across areca use groups. The findings for change in body fatness follow a comparable pattern within and across sexes, as indicated in Table 4. After having established homogeneity of the slopes of the relationship between age and change in percentage body fat across each user category, analysis of covariance indicated statistically significant differences across categories for change in fatness in women.

Table 3. Age, body mass index (BMI), and percentage change in BMI by areca-use pattern in Iban men and Iban women

	Age (years)		BMI (kg/m^2)		%δBMI		
	Mean	SD	Mean	SD	Mean	SD	No.
Iban men							
Non-users	51.2	15.4	20.8	2.7	0.5	6.7	243
Occasional	40.6	8.9	21.3	2.4	0.5	7.1	51
Daily	50.8	15.9	22.0	4.6	3.0	10.1	21
Daily quid	70.0	9.7	18.7	2.0	–2.6	3.3	10
Total	50.1	15.4	20.9	2.8	0.5	7.0	325
Iban women							
Non-users	48.3	14.7	22.2	4.5	2.8	8.3	170
Occasional	43.3	12.4	23.1	4.3	4.1	9.1	152
Daily	49.6	12.4	22.2	3.8	0.7	8.2	65
Daily quid	61.6	8.4	19.3	3.0	–3.4	7.7	51
Total	48.3	14.0	22.2	4.3	2.2	8.8	438

Iban men – Age covariate ‘t’: for BMI –6.7, $P < 0.001$; for %δBMI –5.7, $P < 0.001$. F for ANOVA across user groups: for Age 14.0, $P < 0.0001$; for BMI 2.0, not significant; for %δBMI 1.7, not significant. Iban women – Age covariate ‘t’: for BMI –9.0, $P < 0.001$; for %δBMI –6.2, $P < 0.001$. F for ANOVA across user groups: for Age 25.8, $P < 0.0001$; for BMI 1.6, not significant; for %δBMI 3.5, $P < 0.02$.

Table 4. Percentage body fat in 1996 (%Fat), change in fatness since 1996 (δ%Fat), and mean change in fatness adjusted for age (Adjusted δ%Fat), by pattern of areca use in men and women

	%Fat		δ%Fat		Adjusted δ%Fat	
	Mean	SD	Mean	SD	Mean	No.
Men						
Non-users	19.3	5.3	3.3	3.5	3.1	235
Occasional	19.3	5.0	3.5	3.3	2.7	50
Daily	21.3	7.8	4.0	4.8	3.9	18
Daily quid	16.7	3.9	1.3	2.1	2.4	10
Total	19.3	5.3	3.3	3.5		313
Women						
Non-users	33.4	6.4	3.9	4.0	3.8	143
Occasional	34.4	5.8	4.6	4.3	4.0	133
Daily	34.1	5.8	3.7	3.9	3.6	58
Daily quid	30.7	6.4	0.8	4.3	1.7	48
Total	33.5	6.1	3.7	4.3		382

Men – Age covariate ‘t’: for %Fat 2.7, $P < 0.01$; for δ%Fat –4.9, $P < 0.001$. F for ANCOVA across groups: for %Fat 2.5, not significant; for δ%Fat 0.7, not significant. Women – Age covariate ‘t’: for %Fat –1.8, not significant; for δ%Fat –5.6, $P < 0.001$. F for ANCOVA across groups: for %Fat 2.6, not significant; for δ%Fat 3.7, $P < 0.01$.

Table 5. Effect on r^2 of determinants of body mass index and percentage body fat in 1996

	Determinant	Men r^2	Women r^2
Body mass index			
No.		325	438
1	BMI_{1990} + Age	0.754	0.824
2	Smoking	0.755	0.824
3	Morbidity	0.756	0.828*
4	Hygiene	0.756	0.830†
5	Age^2	0.757	0.830
6	Age^4	0.758	0.830
7–9	Areca use	0.764	0.834†
Percentage body fat			
No.		313	382
1	$\%Fat_{1990}$ + Age	0.583	0.591
2	Smoking	0.589†	0.591
3	Morbidity	0.592	0.601*
4	Hygiene	0.596	0.615**
5	Age^2	0.598	0.637***
6	Age^4	0.601	0.642†
7–9	Areca use	0.606	0.651†

Significance of change in residual sum of squares: †, $P < 0.05$; *, $P < 0.01$; **, $P < 0.001$; ***, $P < 0.0001$.

However, body fatness is sensitive to being confounded by effects of smoking behaviour, socio-economic status, morbidity, and the possibly linear or curvilinear relationship of body composition with age in this population.[41] In order to test the significance of areca use for BMI and body fatness in 1996, multiple regression analysis was used sequentially to construct a series of models. Table 5 shows that for men marginal increments in the r^2 occurred with the addition of most variables to the model. However, the only statistically significant reduction in the residual sum of squares was achieved by adding smoker status to the baseline model of percentage body fat in 1990 with age. Thus in men, areca use did not significantly improve the percentage variance explained for either BMI or percentage body fat.

The picture for women was quite distinct. For the BMI, adding morbidity, hygiene, and areca use slightly but significantly increased the r^2 with inclusion of each variable. For percentage body fat, the model shown is consistent with that for the BMI and shows more marked effects. This model also indicates the importance of allowing for the non-linear relationship between age and body composition by using a polynomial in fourth degree. Respectively for the BMI and fatness, areca use explained about 0.4% and 0.9% of the variance. Thus, its contribution was slight.

Table 6 presents the final regression equation for percentage body fatness. The decreasing coefficients for the dummy variables representing categories of successively more intensive areca use suggest that there may be a graduated dose–response effect of areca chewing on body fatness in this population. However, only the coefficient for ‘daily quid’ users was statistically significant. This finding may therefore result from the inclusion of tobacco in the areca nut quid by the majority of this subgroup of users.

Discussion

The evidence from this study suggests that use of the areca nut may slightly but significantly attenuate age-related increments in the body weight and fatness of adults. Such effects may be the outcome of modulating appetite for food or of altered patterns of energy expenditure and metabolic fuel utilisation. Reporting studies of resting metabolic rate (RMR) in Sarawaki users and non-users of the areca nut, we speculated that there was evidence for a prolonged thermogenic effect of areca use.[33] Tables 7 and 8 reproduce the results of that study. They also show results of a regression model showing a significant change in r^2 associated with areca use in men but not in women. These findings also suggested a highly significant effect of maximum daytime temperatures on subsequent RMR in both sexes.[33] This effect interacted with areca use in women, users showing a relationship which was absent in non-users.[33] However, without further empirical studies to substantiate these observations, the extent to which areca use has contributed to variation in body fatness and the nature of the underlying mechanisms must remain speculative. The following discussion is therefore theoretical.

Table 6. Regression analysis of percentage body fat in 1996 in women

Determinant	Slope	Standardized β	P^a
$\%Fat_{1990}$	0.86	0.73	***
Age	0.81	1.81	*
Smoking	–0.69	–0.04	ns
Morbidity	–0.97	–0.07	†
Hygiene	1.59	0.12	**
Age^2	–0.01	–2.51	*
Age^4	3.82×10^{-7}	0.55	ns
Areca occasionally	0.40	0.03	ns
Areca daily	–0.03	–0.00	ns
Quid daily	–1.79	–0.10	*
Intercept	–6.70		ns

[a], Significance of ‘t’ for each coefficient: †, $P < 0.05$; *, $P < 0.01$; **, $P < 0.001$; ***, $P < 0.0001$. ns, not significant.

Table 7. Resting metabolic rate in Iban men and women by areca use

	No.	Observed RMR Mean	SD	Adjusted RMR Mean
Men				
Non-users	32	6020	981	6122
Users	22	6448	882	6347
F_1		4.9†		
F_2				1.0
Women				
Non-users	23	5462	683	5612
Users	46	5576	997	5425
F_1		0.0		
F_2				1.1

F_1, F ratio after adjusting for age, haemoglobin, height, weight, $\log_{10}\Sigma 4sf$. F_2, F ratio after adjusting also for max temperature °C^2 and max temperature °C^6. RMR, resting metabolic rate; †, $P < 0.05$.

Table 8. Effect on r^2 of determinants of resting metabolic rate

	Determinant	Men $n = 54$ r^2	Women $n = 69$ r^2
1	Age	0.101	0.07
2	Hb	0.133	0.094
3	Height	0.159	0.104
4	Weight	0.187	0.306***
5	$\log_{10}\Sigma 4sf$	0.227	0.331
6	Areca use	0.300†	0.331
7–8	MaxT°C^2 & MaxT°C^6	0.486**	0.505***

Significance of change in residual sum of squares: †, $P < 0.05$; **, $P < 0.001$; ***, $P < 0.0001$. All regressions significant at $P < 0.05$ or better, except equation 3 for women. T, temperature.

The major pharmacologically active agents in the areca nut are the alkaloids which comprise about 0.15–0.67% of the uncured nut.[15] The principal alkaloid is arecoline, contributing 0.07–0.5% of uncured nuts, while arecaidine and guvacine are present in small quantities.[15] Nuts processed by drying, boiling, or roasting may show higher mean arecoline concentrations of 0.5–0.9%.[47] Traditional fermentation procedures may increase this further.[14]

The three principal alkaloids are known to be neuroactive. Arecoline and its metabolite arecaidine activate muscarinic receptors, and arecoline is also a nicotinic receptor agonist. Their effects are thus mainly parasympathomimetic and resemble those of acetylcholine (ACh).[48] Arecaidine and guvacine inhibit uptake of the central inhibitory neurotransmitter γ-amino-butyric acid (GABA).[49]

Experimental studies on rodents suggest that arecoline induces dose-dependent changes in ACh and 5-hydroxytryptamine (5-HT, serotonin) in the whole brain.[50,51] Both neurotransmitters are known to play a role in hypothalamic monoaminergic systems of mammalian thermoregulation,[52,53] and are implicated in pathways modulating the intake and metabolism of macronutrients.[54] Thus, 5-HT-ergic pathways have been a particular focus in the investigation of feeding behaviour, and of systems monitoring glucose ingestion and plasma amino acid profiles.[55] Further, the potent anorectic agent dexfenfluramine is a 5-HT-ergic compound which in addition induces thermogenic effects in the fasted and postprandial states, perhaps to a greater extent in men than in women.[56,57] Thus, there is at least an arguable case for further investigation of the role of areca nut in modulating pathways which monitor and influence energy turnover and nutritional status outcomes.

Conclusion

Evidence was adduced to suggest that areca chewing by women is associated with a slight but significant reduction of gain in body mass index and in fatness over six years when compared across groups of users and non-users. A similar pattern in men did not reach statistical significance. Associations between resting metabolic rate and areca use interacted with the thermal environment in ways which differed between the sexes. These findings are consistent with the hypothesis that pharmacological properties of the areca nut influence body composition, perhaps through 5-HT-mediated effects on energy metabolism and appetite.

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