Optimal physicochemical properties of dried litchis for Thai consumers

Marcelo Precoppe[1*], Marcus Nagle[1], Busarakorn Mahayothee[2], Patchimaporn Udomkun[1], Serm Janjai[3], Joachim Müller[1]

(1. *Institute of Agricultural Engineering in the Tropics and Subtropics* (*440e*), *Universität Hohenheim, Garbenstr. 9, D-70593, Stuttgart, Germany;*
2. *Department of Food Technology, Silpakorn University, 73000 Nakhon Pathom, Thailand;*
3. *Department of Physics, Silpakorn University, 73000 Nakhon Pathom, Thailand*)

Abstract: The litchi is a fruit essential for the economies of several Southeast Asian countries, but markets regularly reject it, mainly due to spoilage. Drying extends the shelf-life of litchis, but in Thailand the optimal characteristics of the dried product have not yet been determined. The purpose of this study was to determine the optimum physicochemical properties of dried litchis – those suitable for Thai consumers. The dried fruits were submitted to physicochemical measurement and consumer evaluation, with datasets subsequently integrated using circular ideal-point regression analysis. Response surface methodology was then used to predict the optimum physicochemical properties of the fruits. It was found that Thai consumer preferences with regard to dried litchis are for the fruits to be of golden-yellow color (L^* ranging around 54; H ranging around 79°), to have a soft flesh (SMF ranging between 13 and 14 kN/100 g) and to have a sweet taste (TSS:TA ranging between 25 and 28). The results may be used in the future to prescribe pretreatments and drying conditions.

Keywords: consumer preference, response surface methodology, circular ideal-point regression, product optimization, market acceptance, lychee
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1 Introduction

Litchi (*Litchi chinensis* Sonn.) is a seasonal tropical fruit grown mainly in Southeast Asia[1]. Litchis have a high commercial value on the international market[2] and are important for the economies of the countries that grow them[1]. Litchis are appreciated for their sweet-acidic taste, fragrant aroma, nutritive value and red pericarp[3]. After harvesting, litchis have a shelf life of 3 to 5 days, but when kept at temperatures of between 2 °C

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Biographies: Marcus Nagle, PhD, research interests: postharvest technology; drying. Phone: +49 711 459 23119; Fax: +49 711 459 23298; Email: marcus.nagle@uni-hohenheim.de
Busarakorn Mahayothee, PhD, Professor, Faculty of Engineering and Industrial Technology, research interests: drying; non-destructive techniques for food analysis. Phone: +66 34 21936; Fax: +66 34 272194; Email: busarakornm@yahoo.com.
Patchimaporn Udomkun, PhD candidate, research interests: drying procedures development and optimizatoin. Phone: +49 711 459 22840; Fax: +49 711 459 23298; Email: patchimaporn.udomkun@uni-hohenheim.de.
Serm Janjai, PhD, Professor, Faculty of Science, research interest: modeling and optimization of dryers. Phone: +66 3427 0222 24; Fax: +66 3425 5099; Email: serm@ su.ac.th.
Joachim Müller, PhD, Professor, Head of Tropics and Subtropics Group, research interests: postharvest technology; energy conservation. Phone: +49 711 459 22490; Fax: 49 711 459 23298; Email: joachim.mueller@uni-hohenheim.de.
***Corresponding author: Marcelo Precoppe**, PhD, research interests: postharvest technology; small-scale agro-processing. Mailing address: Institute of Agricultural Engineering (440e), Garbenstr. 9, D-70593, Universität Hohenheim, Stuttgart, Germany. Phone: +49 711 459 22840; Fax: +49 711 459 23298; Email: marcelo.precoppe@ uni-hohenheim.de.

and 5°C, can be stored for about 20 days, though they deteriorate rapidly after returning to ambient conditions[4]. Nowadays, only 40% of Thailand's litchi production reaches the international market, and while litchi exports could be expanded, a cool-chain system is not well established in Thailand[5]. Due to the related spoilage, markets reject substantial quantities of litchis; however, drying can significantly extend the shelf-life of litchis and ensure their year-round availability[6]. Litchi drying was originally developed in China and is the oldest processing method known in terms of litchi fruit conservation[7]. Dried litchis are popular in Asia[8] and well known in Thailand[9]. However, consumer preferences for the dried product have not yet been determined. The purpose of this study was to determine the physicochemical properties of dried litchis, properties that are optimal from a Thai consumer point of view. Multi-product tests were performed with one commercial and five prototype products, and circular ideal-point regression analysis was used to relate the fruits' physicochemical properties to consumer attribute ratings. As a result, the optimum color, sugar/acidity ratio and hardness of the dried litchis were determined.

2 Material and methods

2.1 Product preparation

A total of six different product types were used in this study – one commercial dried fruit (*C*1) and five prototype dried fruits (*P*1–*P*5). While the commercial dried litchis were purchased from a farmers' cooperative located in the village of Fang, Chiang Mai Province in northern Thailand, the prototype dried fruits were prepared in a dryer using different temperature regimes at a farmers' cooperative located in the village of Mae Sa Mai – also in Chiang Mai Province.

In Fang, before drying, the fruits were peeled, deseeded and boiled in a sugar solution. After boiling, the fruits were left in the solution for 8 hours and then rinsed with water before being arranged next to each other on a perforated drying tray, forming a single layer. The fruits were dried in a multi-story barn, similar to the one described by Tippayawong et al.[10], which had a loading capacity of 800 kg of fresh, peeled and deseeded litchis per batch. The drying process lasted 15 hours, with firewood used as the heat source and with a target temperature of 60°C.

At Mae Sa Mai, the five prototype fruits were prepared using different stepwise temperature regimes. The regimes differed in terms of the number of steps (2–4 steps), the duration of the steps (1–10 hours), the drying air temperature (57–75°C), and the duration of the drying period (8.5–15.5 hours), as shown in Figure 1. The same pretreatments were then applied to the five prototypes, following a procedure typical for the chosen cooperative, so for each drying batch 350 kg of fresh litchi was purchased from local orchards, with only ripe, high-grade litchi of the 'hong-huay' variety used. Before drying, the fruits were peeled, deseeded and immersed in a 0.03% (w/v) citric acid solution, followed by immersion in 0.05% (w/v) potassium metabisulphite solution for 7 minutes. After that, the fruits were placed on perforated drying trays, as a single layer. The fruits were then dried in a convection batch dryer (D001; Likhitchewan Co., Chiang Mai, Thailand) with a loading capacity of 200 kg and fuelled by liquefied petroleum gas (LPG). The air temperature inside the drying chamber was recorded using 27 autonomous miniature thermometer data loggers (SugarCube Clima; Meilhaus Electronic, Puchheim, Germany).

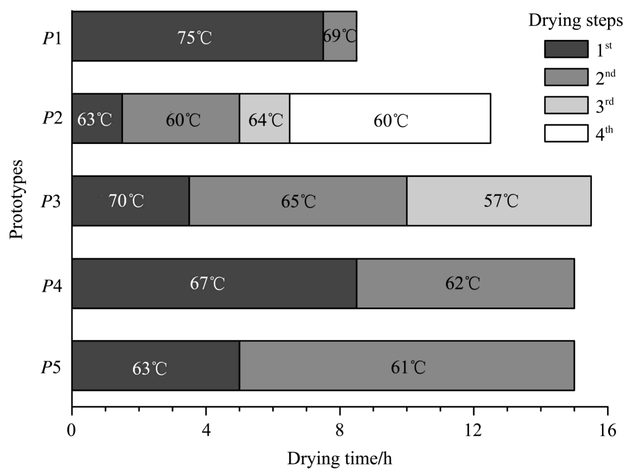

Figure 1 Temperature and duration of the drying steps used to produce the prototype fruits (*P*1–*P*5)

2.2 Physical and chemical analyses

The fruits were evaluated for their moisture content (X), water activity (a_w), color, texture, acidity and sugar content. Moisture content was expressed in terms of the wet basis (wb), with the evaluation performed in quintuplicate using the static gravimetric method[11]. The temperature was kept at 103°C until a constant weight was reached (app. 72 h) using a convection laboratory oven (UFB 500; Memmert Co., Schwabach, Germany).

Water activity was determined using a digital hygrometer (AW-DIO; Rotronic, Bassersdorf, Switzerland). The fruits were finely chopped and placed in a thermostatic measuring chamber at 25°C, with readings taken after 20 minutes to allow the water in the air to equilibrate with the sample[12]. The water activity tests were performed in triplicate.

Color was measured with a colorimeter (CR-300; Minolta, Osaka, Japan), using CIELAB color space and D65 illumination. Color values were expressed as L^* – describing lightness, a^* – describing red-green intensity and b^* – describing yellow-blue intensity. The hue angle (H) was calculated as $H = \arctan(b^*/a^*)$. Two readings were made per fruit, with there being 25 fruits per product-type. The colorimeter head was placed directly against the dried flesh, above a white surface.

Texture was evaluated by the specific maximum force (SMF) method, and expressed as kN per 100 grams of dried fruits[13]. Measurements were performed using a Universal Testing System (Model 3365; Instron, Norwood, USA) equipped with a Kramer Shear Cell and a 5 kN load cell set at a crosshead speed of 100 mm/min. Tests were performed in triplicate using 22.5 g of dried litchi.

Total soluble solids (TSS) content was assessed using the refractometer method[14] and a digital refractometer (PR-201; ATAGO Co., Tokyo, Japan). To perform the readings, 5.0 g of dried fruits was homogenized with 45.0 g of distilled water. The values produced were expressed as °Brix, with the tests performed in triplicate.

Titratable acidity was obtained through alkaline titration[15] using an electrometric titrator (Model 678 EP/KF; Metrohm, Herisau, Switzerland). A solution was prepared by homogenizing 5.0 g of dried litchis with 300.0 mL of distilled water, with titration volumes recorded at pH 7.0 and 8.1. Titratable acidity (TA) was expressed as grams of anhydrous citric acid per 100 grams of dried fruits, and again, the tests were performed in triplicate. The division of TSS by TA yielded the sugar/acid ratio (TSS:TA).

The fruits' physical and chemical properties were compared using the one-way analysis of variance (ANOVA) method, with significant differences among physicochemical mean values estimated using the least significant difference (LSD) method with a 5% probability level. As suggested by Piepho[16] the results were subsequently displayed as a list, using lower-case superscript letters to show whether or not the comparisons were statistically significant. In the results, means sharing a common letter indicate that no significant differences were found, while means followed by different letters indicate that significant differences were obtained. The data were evaluated for normality by comparing the residual distribution with the normal distribution using a Quantile-Quantile-plot.

2.3 Consumer evaluation

Central location tests (CLT) were conducted with consumers in university classrooms at two sites: Chiang Mai and Nakhon Pathom, both in Thailand. Participants were recruited using fliers, posters placed on notice boards and e-mails. Demographic information (age, gender, product usage, etc.) and background information were collected. A total of 50 Thai respondents (age ranging from 21 to 38 years old) including, lecturers, students and cleaning staff, evaluated the six products ($C1$, $P1$–$P5$), with evaluation conducted as a complete randomized block design, meaning the subjects received the sample sets in a balanced randomized order. The fruits were served on white plastic plates, each labeled with a three-digit code and with samples presented just once, sequentially. After tasting each product, consumers were given water and plain crackers for palate cleansing purposes. The survey featured questions about product appearance, texture and taste, and consumer ratings were measured using a nine-point just-about-right (JAR) scale and a nine-point hedonic scale. The JAR scale was anchored at the extremes, with 'too low' on the left, 'optimum' at the midpoint and 'too high' on the right. The hedonic scale was anchored with 'dislike extremely' on the left, 'neutral' at the midpoint and 'like extremely' on the right. Prior to evaluation, the use of the scales was explained and demonstrated.

To facilitate data visualization, five was subtracted from each of the JAR values, thus shifting the 'optimum' to zero, as suggested by Moskowitz et al.[17] In this way, positive values would denote product attribute over-delivery and negative values would denote under-delivery. The product ratings were compared using ANOVA and by treating consumers as a block. Any significant differences in the ratings were estimated using LSD with a 5% probability level, and the distribution of the response data was analyzed through use of a histogram and by calculating the kurtosis and skewness coefficient for each product, as recommended by Gacula and Singh[18].

2.4 Determination of the optimal properties

Determination of the optimal physicochemical properties followed the steps suggested by Moskowitz[19] – for product optimization. The physical and chemical measurements were transformed using factor analysis into uncorrelated and parsimonious factor scores, allowing them to be used as independent variables. Only factors with eigenvalues (λ) higher than 1.5 were retained, and the factor analysis itself used the principal component method. Scores were rotated through varimax for a better visualization of the factor loadings (δ), and circular ideal-point regression analysis[20] was used to relate the factor scores to each attribute rated by the consumers and also to each physicochemical measurement. Response surface methodology (RSM) was used to identify the factor scores for the theoretical, optimized products, but the algorithm was constrained in order to ensure that the identified factor scores were within the range of the factor scores for the tested products. Table 1 shows the RSM target profiles ($t1$–$t10$) of the theoretical, optimized products. The identified factor scores were then entered into the circular ideal-point equations, yielding the predicted, optimum physicochemical properties and the predicted consumer attribute ratings. The calculation steps are shown in Figure 2.

Table 1 Target profiles (*t*1–*t*10) used to determine the optimal physical and chemical properties of dried litchis ('9' meaning 'like extremely' at the hedonic scale and '0' meaning 'optimum' at the just-about-right scale)

Product Attribute	*t*1	*t*2	*t*3	*t*4	*t*5	*t*6	*t*7	*t*8	*t*9	*t*10
Hedonic Color							9	9	9	
Hedonic Lightness							9	9	9	
Hedonic Hardness							9	9	9	
Hedonic Sweetness							9	9	9	
Hedonic Sourness							9	9	9	
Hedonic Overall Appear.	9				9	9	9	9		
Hedonic Overall Texture		9			9	9	9	9		
Hedonic Overall Taste			9		9	9	9	9		
Hedonic Overall Product				9		9	9	9		
JAR Color								0	0	0
JAR Lightness								0	0	0
JAR Hardness								0	0	0
JAR Sweetness								0	0	0
JAR Sourness								0	0	0

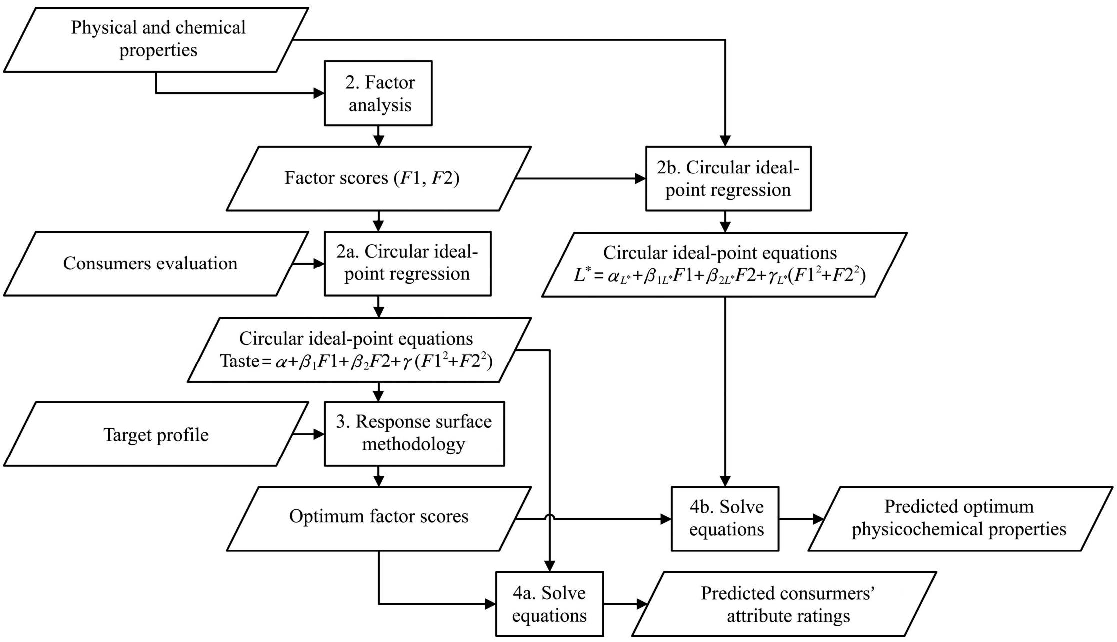

Figure 2 Calculation process used for determination of the optimum physicochemical properties of dried litchis

2.5 Geometrical representation of optimized products

The optimized products (*T*1–*T*10) were verified using a geometric representation, as suggested by Moskowitz[21], plotted on a Factor 1 vs. Factor 2 dimension together with the factor loadings, and then superimposed with the overall product liking surface, a surface created from a circular ideal-point regression analysis.

All the procedures were performed using SAS 9.2 (SAS Institute Inc., Cary, USA).

3 Results and discussion

3.1 Physicochemical properties and attribute ratings

The moisture content of the evaluated products was on average 27.1% ± 4.8% wb, with the highest *X* being 30.94% wb for product *P*4. Kuhn[8] detected mold growth on dried litchis with an X>30% wb. However, for this study, no product had an a_w value above 0.6 – the recommended upper limit for microbiological stability[22]. Lightness values here ranged from 52.2 to 58.5. Janjai et al.[23] carried out experiments using a comparable temperature range but without performing any pretreatment, and obtained darker fruits. The product hue angle varied from 78.1° to 80.9°, which is within the range established by Mahayothee et al.[24] based on the products they studied. The obtained SMF varied from 10.0 to 20.9 kN/100 g, which is almost ten times harder than the canned product[25]. Table 2 shows the measured physicochemical properties of the tested products.

Table 2 Product moisture content on a wet basis (*X*), plus the water activity (a_w), lightness (*L), hue angle (*H*), specific maximum force (SMF) and sugar/acidity ratio (TSS:TA) of commercial dried litchis (*C*1) and five prototype fruits (*P*1–*P*5)**

Product	*X* /% wb	a_w	*L**	*H* /(°)	SMF /kN·100 g^{-1}	TSS:TA
*C*1	18.01^{a}	0.47^{a}	56.56^{c}	80.93^{c}	20.93^{c}	69.97^{e}
*P*1	26.26^{b}	0.49^{b}	52.16^{a}	78.05^{a}	16.14^{b}	26.43^{bc}
*P*2	29.65^{d}	0.53^{c}	55.35^{bc}	79.14^{ab}	12.00^{a}	28.79^{d}
*P*3	27.34^{c}	0.47^{a}	54.45^{bc}	79.67^{bc}	14.66^{b}	27.08^{c}
*P*4	30.94^{e}	0.56^{d}	56.57^{c}	79.81^{bc}	10.02^{a}	25.44^{bc}
*P*5	30.03^{d}	0.53^{c}	58.47^{d}	80.28^{bc}	10.75^{a}	20.42^{a}

Note: Different letters in the same column indicate significant differences at a probability level of 5%.

Average hedonic ratings taken from the consumer evaluation are presented in Table 3 and the average JAR ratings are shown in Table 4. From a consumer perspective, then for color, lightness and overall appearance, product *P*3 was the most liked, whereas product *C*1 (the hardest; SMF=20.9 ± 0.1 kN/100 g) was the least liked by the consumers in terms of hardness and texture. Product *P*4 was the softest (SMF=10.0 ± 0.2 kN/100 g) fruit and; thus, the most appreciated by the consumers with respect to hardness and texture, and while product *C*1 had the highest sugar content (TSS= 75.22 ± 1.2 °Brix) and lowest acidity level (TA=1.075 ± 0.060 g/100 g), it was product *P*3 (TSS=74.45 ± 3.45 °Brix; TA=2.749 g/100 g) that was most appreciated for its sweetness, sourness and overall taste. Product *P*3 also received the highest overall product acceptance rating.

Table 3 Average Thai consumer ratings (based on a 9-point hedonic scale) for commercial dried litchis (*C*1) and five prototype fruits (*P*1–*P*5)

Product	Light.	Color	Hard.	Sweet.	Sour.	Overall			
						App.	Text.	Taste	Prod.
*C*1	3.4^{a}	3.2^{a}	4.0^{a}	5.3^{bc}	4.5^{a}	4.5^{a}	4.7^{a}	4.2^{ab}	3.9^{a}
*P*1	5.4^{bc}	5.2^{b}	5.4^{b}	5.0^{bc}	5.6^{bc}	5.6^{bc}	5.3^{ab}	5.6^{d}	5.5^{cd}
*P*2	5.0^{b}	4.8^{b}	5.2^{b}	5.0^{bc}	5.0^{ab}	5.2^{b}	5.6^{bd}	5.1^{cd}	5.3^{bc}
*P*3	5.9^{c}	6.1^{c}	5.2^{b}	5.4^{c}	5.7^{c}	6.2^{c}	5.9^{cd}	5.8^{d}	6.1^{d}
*P*4	5.4^{bc}	5.4^{bc}	5.6^{b}	4.6^{b}	5.0^{ab}	6.0^{c}	6.0^{d}	4.8^{cb}	5.4^{c}
*P*5	5.1^{b}	5.2^{b}	5.5^{b}	3.6^{a}	4.7^{a}	5.6^{bc}	5.4^{cb}	4.0^{a}	4.6^{b}

Note: Different letters in the same column indicate significant differences at a probability level of 5%.

Table 4 Average Thai consumer just-about-right ratings (0 = optimum) for commercial dried litchis (*C*1) and five prototype fruits (*P*1–*P*5)

Prod.	Light.	Color	Hard.	Sweet.	Sour.
*C*1	-2.3^{a}	-2.8^{a}	-1.0^{a}	0.5^{c}	-1.8^{a}
*P*1	1.4^{d}	1.3^{e}	-0.0^{b}	-0.7^{b}	1.2^{cd}
*P*2	0.7^{c}	0.8^{de}	0.1^{b}	-0.6^{b}	0.5^{b}
*P*3	0.4^{c}	0.2^{c}	-0.8^{a}	-0.5^{b}	0.5^{b}
*P*4	0.5^{c}	0.5^{cd}	0.6^{bc}	-1.0^{b}	1.0^{bc}
*P*5	-0.3^{b}	-0.6^{b}	1.0^{c}	-1.6^{a}	1.8^{d}

Note: Different letters in the same column indicate significant differences at a probability level of 5%.

The JAR scale shows consumer liking for the fruits and sensory descriptive information simultaneously, and although some products revealed JAR ratings close to zero, the same attributes did not receive a high rating on the hedonic scale. Ekpong et al.[26] observed that Thai consumers perform well on sensory descriptive attribute ratings, but Yeh et al.[27] detected that, for how much they like a product, they tend not to explore the full extent of the 9-point hedonic scale, and this fact would seem to explain the inconsistency between scales noticed here. This contradiction between the hedonic and the JAR scales have been also observed on other studies[28-30].

3.2 Optimal properties and predicted ratings

Factor analysis reduced the physicochemical measurements to two orthogonal factors ($F1$ & $F2$), accounting for 97.5% of the total variability, with 55.1% accounted by $F1$ (λ=2.20) and 42.4% by $F2$ (λ=1.69). $F1$ was mainly correlated to SMF (δ=0.511) and TSS:TA (δ=0.463), while $F2$ was mainly correlated to lightness (δ=0.529) and hue angle (δ=0.470). Table 5 shows the predicted physicochemical properties obtained from the RSM while Table 6 shows the coefficients of the circular ideal-point equations, those that allowed the prediction of physicochemical properties and consumer attribute ratings from the factor scores. From the optimization work based on $t3$, the target profile that had the maximum score for overall taste yielded $T3$ – the product with the highest TSS:TA; however, when basing the optimization on $t1$, the target profile that had the maximum score for appearance did not yield a product with the highest L^* and H values. Similarly, the optimization based on $t2$, the target profile with the maximum score for texture did not yield the softest product.

Table 5 Predicted lightness (L^*), hue angle (H), specific maximum force (SMF) and sugar/acidity ratio (TSS:TA) content for the 10 optimized products ($T1$–$T10$)

Prod.	L^*	H/(°)	SMF/kN·100 g^{-1}	TSS:TA
$T1$	54.91	78.84	11.02	15.06
$T2$	55.34	79.54	12.42	26.55
$T3$	53.19	78.96	16.06	34.94
$T4$	53.92	79.05	13.97	28.06
$T5$	54.17	79.14	13.65	27.69
$T6$	54.09	79.11	13.74	27.8
$T7$	53.97	78.94	13.42	25.05
$T8$	54.1	79.14	13.82	28.3
$T9$	54.1	79.14	13.85	28.48
$T10$	55.87	80	13.26	33.48

Table 6 Intercept (α) and coefficients (β_1, β_2, γ) for the circular ideal-point equations (Attribute = $\alpha+\beta_1F1+\beta_2F2+\gamma(F1^2+F2^2)$) – relating factor scores ($F1$ & $F2$) to lightness (L^*), hue angle (H), specific maximum force (SMF), sugar/acidity ratio (TSS:TA) and consumer ratings

Attribute	α	β_1	β_2	γ
L^*	55.26	−0.62	2.09	0.2
H	79.79	0.43	0.92	−0.08
SMF	13.69	3.72	−0.65	0.24
TSS:TA	33.38	17.48	5.25	−0.22
Hedonic Color	5.39	−0.47	−0.29	−0.24
Hedonic Lightness	5.34	−0.45	−0.36	−0.19
Hedonic Hardness	5.04	−0.62	−0.15	0.05
Hedonic Sweetness	5.4	0.81	−0.30	−0.35
Hedonic Sourness	5.31	0.03	−0.41	−0.14
Hedonic Overall Appear.	5.74	−0.28	−0.14	−0.14
Hedonic Overall Texture	5.85	−0.15	−0.03	−0.21
Hedonic Overall Taste	5.4	0.23	−0.58	−0.30
Hedonic Overall Product	5.67	−0.05	−0.45	−0.32
JAR Color	0.13	−0.87	−0.99	−0.13
JAR Lightness	0.19	−0.83	−0.91	−0.07
JAR Hardness	−0.54	−1.02	0.14	0.32
JAR Sweetness	−0.36	0.83	−0.03	−0.17
JAR Sourness	0.02	−1.47	−0.31	0.31

Table 7 and Table 8 show predicted consumer attribute ratings for the optimized target profiles. The highest hedonic ratings for color and lightness were obtained for the optimized product $T1$, but the predicted JAR ratings indicated a deviation from the optimum for these attributes. In contrast, the predicted hardness JAR rating for product $T2$, optimized for texture, was close to zero.

Table 7 Predicted 9-point hedonic attribute ratings for the optimized products ($T1$–$T10$)

Product	Light.	Color	Hard.	Sweet.	Sour.	Overall			
						App.	Text.	Taste	Prod.
$T1$	5.7	5.7	5.7	4.5	5.4	5.9	5.8	5.2	5.6
$T2$	5.5	5.5	5.3	5.1	5.3	5.8	5.9	5.3	5.7
$T3$	5.2	5.3	5	5.6	5.6	5.6	5.6	5.7	5.7
$T4$	5.5	5.5	5.2	5.4	5.5	5.8	5.8	5.6	5.8
$T5$	5.5	5.5	5.2	5.3	5.5	5.8	5.8	5.6	5.8
$T6$	5.5	5.5	5.2	5.3	5.5	5.8	5.8	5.6	5.8
$T7$	5.6	5.6	5.3	5.2	5.5	5.8	5.8	5.6	5.8
$T8$	5.5	5.5	5.2	5.4	5.5	5.8	5.8	5.6	5.8
$T9$	5.5	5.5	5.2	5.4	5.5	5.8	5.8	5.6	5.8
$T10$	5.3	5.3	5	5.2	5.2	5.7	5.8	5.2	5.5

Table 5 shows that the optimum L^* ranges from 53 to 56, the optimum H ranges from 79° to 80°, the optimum SMF ranges from 11 to 16 kN/100 g and the optimum TSS:TA ranges from 15 to 35. However, the geometric representation of the tested and optimized products (Figure 3) reveals that products *T*1 to *T*3 – optimized for a single attribute, are distant from the central preference area as defined by the circular ideal-point surface, and also product *T*10 – whose optimization was based solely on the JAR ratings, does not fall within the highest-rating area. Products *T*4 to *T*9 are all clustered around the central preference area, and fall close together on the map because their physicochemical properties were similar: L^* ranging around 54, *H* ranging around 79°, SMF from 13 to 14 kN/100 g and TSS:TA from 25 to 28.

Table 8 Predicted just-about-right attribute ratings (0 = optimal) for the optimized products (*T*1–*T*10)

Prod.	Light.	Color	Hard.	Sweet.	Sour.
*T*1	1.3	1.3	0.6	−1.3	1.8
*T*2	0.5	0.6	−0.1	−0.7	0.6
*T*3	0.6	0.7	−0.7	−0.2	0.1
*T*4	0.8	0.9	−0.4	−0.5	0.5
*T*5	0.8	0.8	−0.4	−0.5	0.5
*T*6	0.8	0.8	−0.4	−0.5	0.5
*T*7	1	1	−0.2	−0.6	0.8
*T*8	0.8	0.8	−0.4	−0.5	0.5
*T*9	0.8	0.8	−0.4	−0.5	0.5
*T*10	−0.1	0	−0.4	−0.4	0.1

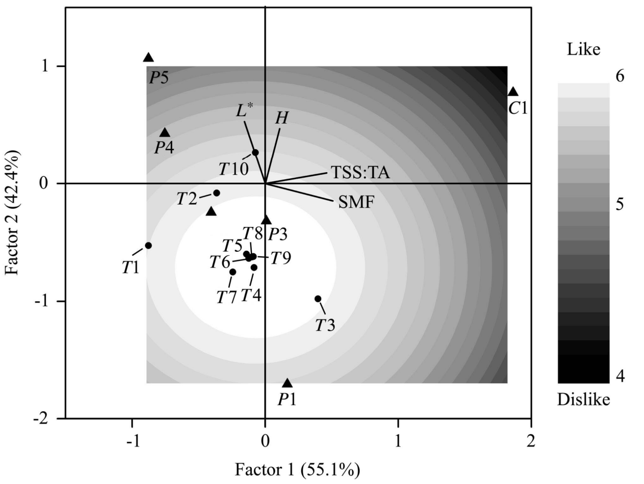

Figure 3 Overall product liking surface created by circular ideal-point regression analysis, with geometric representations of the commercial dried litchis (*C*1), prototype fruits (*P*1–*P*5), optimized products (*T*1–*T*10) and the factor loadings – lightness (L^*), hue angle (*H*), sugar/acidity ratio (TSS:TA) and specific maximum force (SMF)

It can be seen in Figure 3 that on the *F*1 dimension the distribution of tested products is unbalanced; prototypes are concentrated mostly on the left side and *C*1 on the extreme right. Although the differences in SMF and TSS:TA are wide enough, there is not an evenly distributed gradient, a fact mainly related to product moisture content (*P*1–*P*5=28.8 ±2.0% wb, *C*1=18.0% wb) and the pretreatments utilized. The commercial product was pretreated with sugar whereas the prototypes were not – they were immersed in citric acid. As a result, the prototypes were all similar for both SMF (14.1 ±2.6 kN/100 g) and TSS (72.5 ± 2.2 °Brix) and TA (2.6 ±0.4 g/100 g), but differed from the commercial product. For this reason, SMF and TSS:TA could be further optimized by testing products that show gradual differences in hardness, sugar concentration and acidity.

On the *F*2 dimension, the tested products are well distributed. As drying temperature is the main factor influencing the final color of dried litchi[31], the five temperature regimes were successful at producing gradient differences for L^* and *H*.

In Figure 3, products *T*4 to *T*9 – developed from different target profiles, are close to each other in the central preference area. Although their physicochemical properties were similar, the optimization of product *T*4 was based solely on the overall product liking rating, whereas the optimization of products *T*5 to *T*9 depended on a larger number of questions being asked of the consumers. This suggests that product optimization might be best carried out by asking questions only about how much a product is liked overall, and thereby simplifying the consumer evaluation.

4 Conclusions

In this research, with the aid of circular ideal-point regression analysis and RSM, it was possible to predict Thai consumers' optimum physicochemical parameters for dried litchis using only a few products. Although further optimization might still be achievable, the results here will allow for an adjustment of processing parameters, and therefore, represent a step forward in the development of the litchi drying industry.

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