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RESEARCH ARTICLE

Physico-chemical properties of optimized Kaalan-A traditional dairy product

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Abstract: Kaalan is a buttermilk, coconut and vegetable-based culinary preparation filled with the goodness of spices, famous in the South Indian state of Kerala. The Kaalan available in the market differs widely which can be attributed to a lack of well-defined characterization and standardization, hindering efforts towards industrial production. The complex procedures of preparation and lack of knowledge limit its preparation to caterers and households. The current study aimed to optimize the production process utilizing the Response Surface Methodology for achieving standardized large-scale production within the organized sector. The outcomes from the Response Surface Methodology (RSM) demonstrated that the experimental observations could be suitably accommodated within a second-order polynomial model, exhibiting a satisfactory coefficient of determination (R^2 > 90%). The proposed formulation for the Kaalan was a combination containing 194.97g vegetables, 748.09 ml buttermilk, and 126.78g coconut. The optimized Kaalan had 3.49±0.005 per cent protein, 7.12±0.07 per cent fat, 9.95±0.08 per cent carbohydrate, 4.84±0.22 per cent dietary fiber, 2.17±0.03 per cent ash and 28.36±0.04 per cent total solids. The curcumin content was 13.63±0.03 ppm and the energy value was 117.77±0.42 kcalories per 100 g. The data shows that the optimized Kaalan can be established as a nutritionally valuable, low-calorie functional food.

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Introduction

Kerala, a state in southern India, has a diverse and amusing food culture deeply rooted in its traditions and way of life. The cuisine of Kerala is renowned for its abundant use of coconut in various forms and aromatic spices in its flavourful dishes. Sadya is a multi-course meal with a wide variety of vegetarian dishes, typically served on a banana leaf on special occasions and festivals. Kaalan is a traditional culinary preparation native to Kerala and is a significant component of the Sadya. It is a buttermilk-based curry prepared using unripe plantains, elephant foot yam (EFY), and coconut as its primary ingredients. Despite the delightful taste of Kaalan, the younger generation seldom prepares it due to its time-consuming process and limited knowledge about this dish (Aneena, 2009). The significant obstacles faced by the Indian food processing sector are lack of standardization, the absence of proper quality measures, and the high cost for establishing cold chain infrastructure (Singh et al. 2022). These challenges are particularly relevant to the production of Kaalan, because of the lack of information regarding its quality and characteristics. It was found in the study conducted by the same authors that the Kaalan available in the market vary widely in the quality attributes making it difficult to authenticate this traditional product.

The constituents employed in the preparation of Kaalan demonstrate high nutritional properties and present an array of well-established functional characteristics. The elephant foot yam (*Amorphophallus paeoniifolius*) and unripe plantain (*Nendran* variety from *Musa* spp-AAB group) exhibit elevated nutritional, and functional qualities. The coconut (*Cocos nucifera*) serves as a source of medium chain fatty acids renowned for their cardioprotective effects (DebMandal and Mandal, 2011). The tangy flavor and nutrient rich composition of sour buttermilk make it a versatile ingredient in culinary preparations, while its abundant phospholipids and potential health benefits underscore its significance in both traditional and modern contexts. Turmeric (*Curcuma longa*) contains curcumin, a compound possessing anti-inflammatory, antioxidant, anti-bacterial, antifungal, antithrombotic, anti-carcinogenic, neuroprotective, and cardio-protective properties (Khajehdehi, 2012). Remarkably, the inclusion of pepper (*Piper nigrum*) enhances the bioavailability of curcumin present in turmeric (Patil et al. 2016; Shoba et al. 1998). Furthermore, other spices aid in improving digestion. While the functional properties of individual ingredients are well-documented, the synergistic effects in dishes like Kaalan require further validation. In order to preserve the culinary heritage of Kaalan and ensure its endurance for future generations, it is crucial to establish proper standardization, validate its functional properties, and document its properties. Achieving this would also support its industrial production and facilitate its entry into the global market.

Optimization means identifying the optimal quality standards for both the product and process efficiency, all while minimizing time and cost (Bas and Boyaci, 2007). In food preparation, many factors affect the final quality such as quantity and quality of ingredients, their interactions, processing conditions, etc. Response surface methodology (RSM) has emerged as an effective and powerful approach for food product modelling and optimization, offering substantial advantages over traditional single-factor studies. By considering multiple factors together, RSM enables us to thoroughly investigate how different ingredients interact. This approach provides a clearer understanding of the best conditions to achieve desired outcomes in developing and optimizing food products.

In the present study, RSM was used for optimizing the formulation of Kaalan. Further, the physico-chemical characteristics and nutritional value of Kaalan were also analysed. Optimizig the method of preparation and assessing the nutritional and functional properties are of utmost importance to position Kaalan as a high-quality food in the international culinary repertoire and qualify it as a functional food.

Materials and methods

Cow milk was purchased from Kerala Veterinary and Animal Sciences University Dairy Plant, Mannuthy and used for buttermilk preparation. Various starter cultures were procured from the Revolving Fund Project at the Department of Dairy Microbiology, Verghese Kurien Institute of Dairy and Food Technology (VKIDFT), Mannuthy, Thrissur, Kerala. These cultures were screened for their flavour and acid production capabilities. Five starter cultures (Table 1) exhibiting favourable functional properties were chosen for curd preparation. Cow milk was heated to 90°C for 10 minutes, cooled and inoculated with one per cent culture. It was incubated for 12 hours at 37°C, the curd was cooled and churned to remove butter. The buttermilk samples thus obtained were subjected to sensory evaluation using a 9-point hedonic scale. EFY, plantain (*Nedunenthran* variety), coconut and spices such as pepper, turmeric, fenugreek, cumin and mustard were purchased from the local market. Pepper, turmeric, and fenugreek were washed, dried and milled in a domestic mixer grinder separately. Fenugreek was roasted before milling. Prepared spice powders were stored in air tight containers in the refrigerator.

Consumer preferences and methodology for the preparation of Kaalan employed across the state were gathered through a survey conducted among both caterers and households. Kaalan samples were collected from the market and physico-chemical and sensory analyses were carried out on these samples. The samples were ranked based on their sensory scores using a fuzzy logic technique and identified the top/best five samples, details of which can be found elsewhere (Divya *et al.* 2023). The levels of ingredients utilized in the preparation of these top/best five samples as obtained from the questionnaire served as a guide to fix the minimum and maximum levels of factors to be considered in the Response Surface Methodology (RSM) experimental design.

Experimental design

The Central Composite Rotatable Design (CCRD) of Response Surface Methodology (RSM) was utilized to optimize the quantity of major ingredients. The factors considered were the quantity of vegetable blend (EFY and Plantain in 1:1), buttermilk and coconut. The statistical analysis, including Analysis of Variance (ANOVA) and multiple regression tests, was conducted using Design Expert® software (version 13.0.13 of Stat-Ease, Inc, 1300, Godward Street Northeast, Minneapolis, USA). The range of the independent factors viz., vegetables, buttermilk, and coconut, was set from 100g to 350g, 500 ml to 1000ml, and 60g to 200g,

Table 1: Starter cultures tested and corresponding sensory scores

Name of starter culture	Accession Number	Flavour score	Overall Acceptability score
Lactococcus lactis ssp. lactis	NCDC-091/ UD 708	7.33±0.17 [b]	7.17±0.16 [ab]
Lactobacillus delbrueckii ssp. bulgaricus	NCDC-304/ NCIMB 702395	7.50±0.29 [b]	7.5±0.28 [c]
Lactobacillus rhamnosus	NCBI-MT 491095	6.50±0.29 [a]	6.67±0.17 [b]
Lactobacillus helveticus-DM 053	NCBI-MH 191154	6.10±0.26[a]	6.00±0.00 [a]
Lactobacillus fermentum- DM 013	NCBI-KY 379153	8.67±0.17 [c]	8.83±0.17 [d]

respectively. The second-order Central Composite Rotatable Design (CCRD) suggested 20 runs as shown in Table 2. Kaalan was prepared as per traditional procedure (Fig. 1) except for the quantity of buttermilk, coconut, and vegetables. These three ingredients were added according to Table 2. The obtained responses were fed into the software, and the sensory levels of the factors were optimized. The data was fitted to a basic model equation as given in the equation (1).

$$Y = \hat{a}_0 + \hat{a}_1X_1 + \hat{a}_2X_2 + \hat{a}_3X_3 + \hat{a}_{11}X_1^2 + \hat{a}_{22}X_2^2 + \hat{a}_{33}X_3^2 + \hat{a}_{12}X_1X_2 + \hat{a}_{23}X_2X_3 +$$

$$\hat{a}_{31}X_3X_1 + Error\ term \text{————————————} (1)$$

Where Y is the predicted response, β_0 is the constant coefficient, β_1, β_2 and β_3 represent linear coefficients, β_{11}, β_{22} and β_{33} denote quadratic coefficients, β_{12}, β_{23} and β_{31} show interaction coefficients.

The model adequacy was evaluated by the coefficient of determination (R^2), Adequate Precision Value (APV) and the F value (at a 5% level of significance). APV measures the signal-to-noise ratio. The predicted sensory responses corresponding to the optimum levels of the factors were verified using actual responses in a one-sample t-test of SPSS 24 software.

Analysis of optimized product

Total moisture content was determined by the gravimetric method. Fat in the sample was measured using Mojonnier method (AOAC,

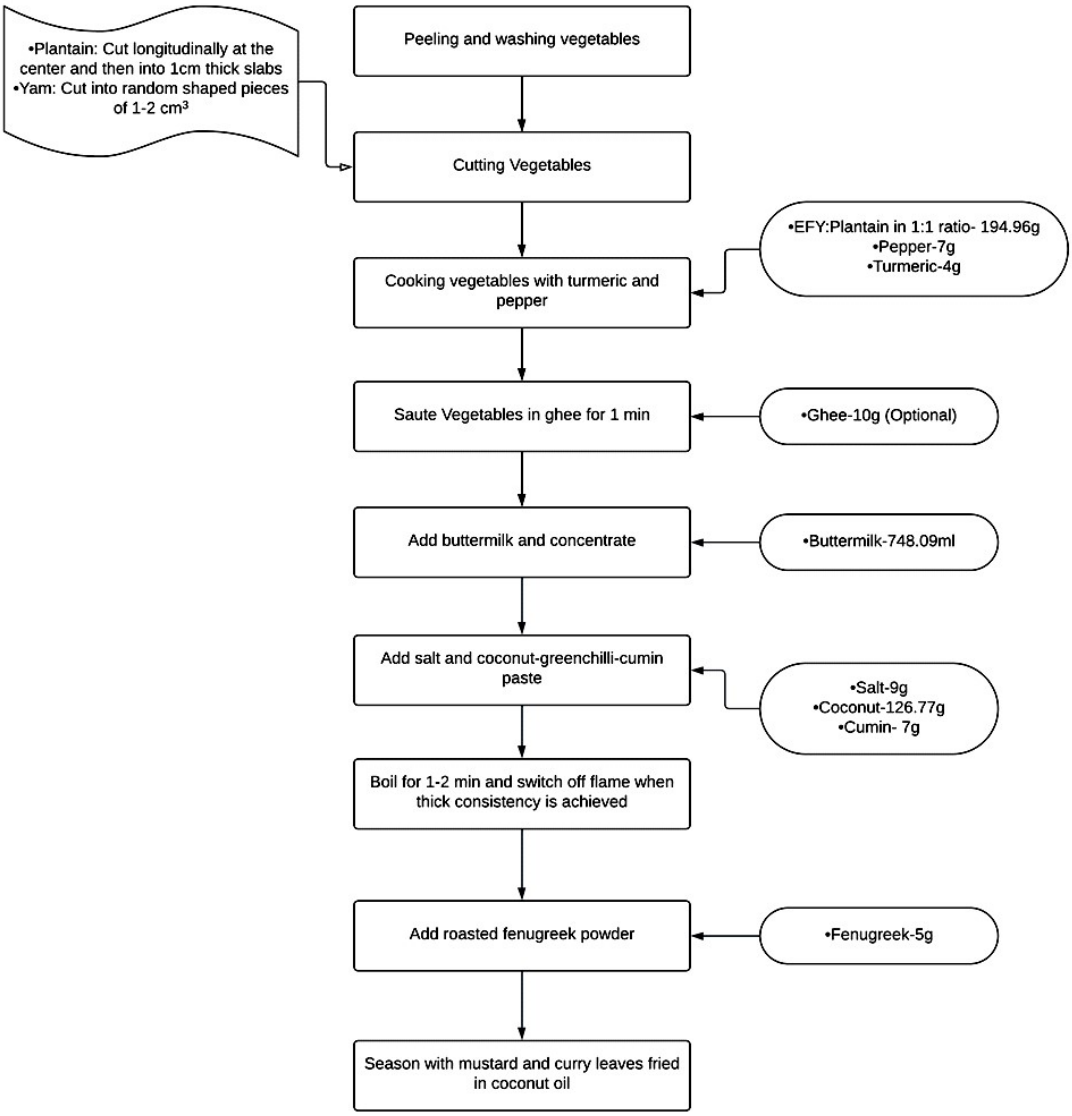

Fig. 1 Flow chart for the preparation of optimized Kaalan

1990) with modifications in sample preparation. The sample was hydrolysed using conc. HCl. Total nitrogen was estimated using Micro Kjeldahl method given in AOAC (2016). Total protein was calculated using a conversion factor of 6.25. The total ash content and total carbohydrate present in the Kaalan samples were also determined (AOAC, 2016). The total dietary fiber content in the product was determined using the 'Total Dietary Fiber Assay Kit' supplied by Sigma Aldrich Inc. (TDF-100A). The analysis uses a combination of enzymatic and gravimetric methods based on AOAC (1997).

The pH of samples was determined immediately after preparation using a portable food pH meter (Model No: HI99161, Hanna Instruments Inc, USA) by immersing the electrode directly into the sample. The titratable acidity was also determined by the titration method recommended by FSSA (2016) and expressed the results as per cent lactic acid. Colour characteristics were measured by reflectance spectroscopy technique employing a reflectance meter, colour flex (Mini Scan EZ 4500 portable spectrophotometer, Virginia, USA). Data were received from the software in terms of 'L' [Lightness, ranges 0 (black) to 100 (White)], 'a' [Redness, ranges from +60 (red) to -60 (green)], and 'b' [Yellowness, ranges from +60 (yellow) to -60 (blue)] values of the international colour system. The water activity of the samples was measured using AQUALAB 4TE water activity meter (Decagon Devices, USA) which is equipped with chilled mirror due point sensor. Curcumin content in the samples were also determined (Maurya et al. 2020). A calibration curve, $y = 0.1667x + 0.05.72$ (R^2 = 0.997) was prepared using curcumin (Sigma Aldrich, USA) as reference and calculated values were expressed in ppm. The energy content of the samples on a wet weight basis was determined using a conversion rate of 4 kilo calories per gram for protein and carbohydrates and 9 kilo calories per gram for fats.

Sensory evaluation

Table 2: Design matrix showing factors and their responses for optimization of Kaalan

Standard Order	Factors			Responses			
	Factor 1 A: Vegetable blend (g)	Factor 2 B: Buttermilk (ml)	Factor 3 C: Coconut (g)	Response 1: Flavour	Response 2: Colour and Appearance	Response 3: Body and Texture	Response 4: Overall acceptability
1	100	500	60	7	7.07	7.43	7.1
2	350	500	60	7.6	7.64	7.5	7.69
3	100	1000	60	7.81	7.56	7.56	7.56
4	350	1000	60	7.29	7.67	7.43	7.5
5	100	500	200	7.06	7.61	7.56	7.44
6	350	500	200	7.36	7.65	7.43	7.36
7	100	1000	200	7.71	7.57	7.43	7.68
8	350	1000	200	6.61	7.45	7.22	7
9	14.78	750	130	7.78	7.67	7.83	7.63
10	435.22	750	130	7.17	7.83	7.4	7.51
11	225	329.55	130	7.68	7.56	7.67	7.5
12	225	1170.45	130	7.45	7.71	7.57	7.32
13	225	750	12.27	6.94	6.89	7.28	7.06
14	225	750	247.73	6.64	7.07	7.14	6.75
15	225	750	130	8	8.1	8	8
16	225	750	130	7.8	7.9	7.83	7.98
17	225	750	130	8.04	8	8	8.11
18	225	750	130	8	7.9	7.92	7.83
19	225	750	130	8.1	7.94	7.92	7.94
20	225	750	130	8.07	8.07	8	8.21

The faculty members of VKIDFT, located in Mannuthy, Kerala, India, underwent a screening process to assess their physical well-being, concentration abilities, and preferences for fermented/ sour dairy products. A total of ten panel members were selected and trained in the specific sensory attributes associated with Kaalan. During the evaluation process, four samples were concurrently presented to the panellists in glass bowls, each identified by a unique three-digit code number. The panellists were provided with scorecards and instructed to assign scores in a 9-point hedonic scale. This scale allowed judges to provide numerical ratings within the range of 1 to 9, for four key quality attributes: flavour, colour and appearance, body and texture, and overall acceptability. The number '1' on the scale represented 'dislike extremely' and the number '9' 'like extremely' (Stone and Sidel, 2004).

Results and Discussion

Selection of starter culture

The cultures of Lactic acid bacteria from the stock of the Department of Dairy Microbiology, VKIDFT were evaluated by looking into skim milk coagulating properties and sensory characteristics. The culture (*Lactobacillus fermentum*) (*Limosilactobacillus fermentum* as per new taxonomy) employed in the preparation of the buttermilk obtained the highest flavour and overall acceptability score and was chosen for product preparation (Table 1). Naghmouchi et al. (2019) conducted a comprehensive review of the biomedical and food preservation attributes of *Lb. fermentum* summarizing it as the cell factories that enhance the effectiveness and nutritional value of functional foods.

Preparation of Kaalan

The principal steps involved in the preparation of Kaalan were cooking EFY and plantain along with turmeric and pepper powder, adding sour buttermilk (*moru*) and concentrating it, adding grated coconut-green chilli-cumin paste followed by final seasoning with fenugreek powder, mustard, and curry leaves fried in coconut oil (Fig. 1). The resultant Kaalan exhibited a creamy texture and a mild, tangy taste with the infusion of coconut and spices.

Effect of different levels of the factors on the sensory attributes of Kaalan

The optimization of the ingredients of Kaalan formulation was done by CCRD of RSM. The factors considered were "vegetable blend", "buttermilk" and "coconut". These three independent factors were selected and set to their levels coded as -1, 0 and +1. The Table 2 illustrates the various treatment combinations for the three independent factors and their sensory responses. The trials are listed in standard order. The aim was to maximize the sensory scores, such as flavour, colour and appearance, body and texture, and overall acceptability. The partial regression coefficients of linear, quadratic and interactive terms for the regression model for each response with their R^2 and Adequate Precision Values (APV) are shown in Table 3. A quadratic regression model was fitted to the experimental data for each response (Table 4). The non-significant lack-of-fit, significant F-test value, R^2 value of more than 0.8, and adequate precision (which indicates signal to noise ratio) of more than four for all the sensory attributes indicate that the model is fit and can give a

Table 3: Regression coefficients of quadratic model and their statistical significance for sensory characteristics of Kaalan

Coefficients	Sensory Responses			
	Flavour	Colour and Appearance	Body and Texture	Overall Acceptability
Intercept	8.00	7.98	7.95	8.01
A-Vegetables	-0.127**	0.064*	-0.082**	-0.0316 ^{ns}
B-Buttermilk	0.001 ^{ns}	0.039 ^{ns}	-0.033 ^{ns}	-0.0112 ^{ns}
C-Coconut	-0.107**	0.047 ^{ns}	-0.038 ^{ns}	-0.0653 ^{ns}
AB	-0.315**	-0.078*	-0.035 ^{ns}	-0.1563**
AC	-0.11*	-0.095*	-0.035 ^{ns}	-0.1613**
BC	-0.075 ^{ns}	-0.095*	-0.050 ^{ns}	-0.0488 ^{ns}
A^2	-0.171**	-0.061*	-0.119**	-0.1214**
B^2	-0.1391**	-0.102**	-0.117**	-0.1780**
C^2	-0.413**	-0.333**	-0.262**	-0.3565**
Model Fit Statistics				
Lack-of-fit	1.84 ^{ns}	1.33 ^{ns}	0.95 ^{ns}	1.26 ^{ns}
Model F-value	28.65**	25.34*	33.33*	15.03*
R^2	0.96	0.96	0.97	0.93
PRESS Value	0.88	0.44	0.207	0.97
APV	16.28	15.53	16.77	11.31

** - Highly significant (p<0.01), *-Significant (p<0.05), ns- non-significant (p>0.05).

good prediction of the parameters under study (Anderson et al. 2017).

A previous study using fuzzy logic by Divya et al. (2024), reported that taste was the primary attribute influencing the acceptability of Kaalan in general, with mouthfeel being the subsequent significant factor. Aroma and colour were ranked lower in terms of their impact on acceptability. A lack of prior research exists pertaining to the sensory attributes of Kaalan or analogous products, thereby impeding comparative analysis. Nevertheless, research studies that employed RSM in fermented dairy foods (Ghosh and Kulkarni, 1991; Manohar, 2005; Manohar and Balasubramanyam, 2007; Modha and Pal, 2011) were referred to for elucidating the influence of ingredients on sensory attributes.

Effect on Flavour

Flavour comprises the taste, aroma, and any discernible physical characteristics of the substance (Bartoshuk et al. 2019). Flavour scores ranged from 6.61 to 8.1 and the maximum score was observed for a combination of central points of experimental design. The coefficient of determination (R^2) was found to be 0.96, with an APV of 16.28. The model F value noted was 28.65 ($p<0.01$) and with a non-significant lack of fit, an adequate model was obtained. The 3-D response plots in Fig. 2a- 2c depict the above data. Considering various factors that impact flavour of Kaalan, it was observed that the quantity of vegetables and coconut had a negative and statistically significant influence ($p<0.01$), while the levels of buttermilk chosen for testing did not exhibit any apparent impact. Moreover, an increase in coconut content was associated with a reduction in the flavour rating. Yaakob et al. (2012) reported that the scent of coconut was generally disliked by most panellists in coconut yogurt, which may be applicable in this context as well. Decrease in flavour score of Kaalan at linear level could be due to the bulkiness formed by higher quantity of the vegetables. The interaction of vegetables with both buttermilk ($p<0.01$) and coconut ($p<0.05$) had a significant negative impact on the flavour of the product. However, the interaction effect of buttermilk and coconut was non-significant. From this, it can be concluded that when the quantity of vegetables and coconut are increased, the flavour of Kaalan get negatively affected as it reduces the tangy flavour of buttermilk and masked the zesty flavour of spices. Similar trend was reflected in Kadhi, where the addition of Bengal gram flour substantially diminished the flavour score (Manohar, 2005). Numerous variables associated with aroma significantly impact the overall food quality. Ensuring the stability of flavours is a

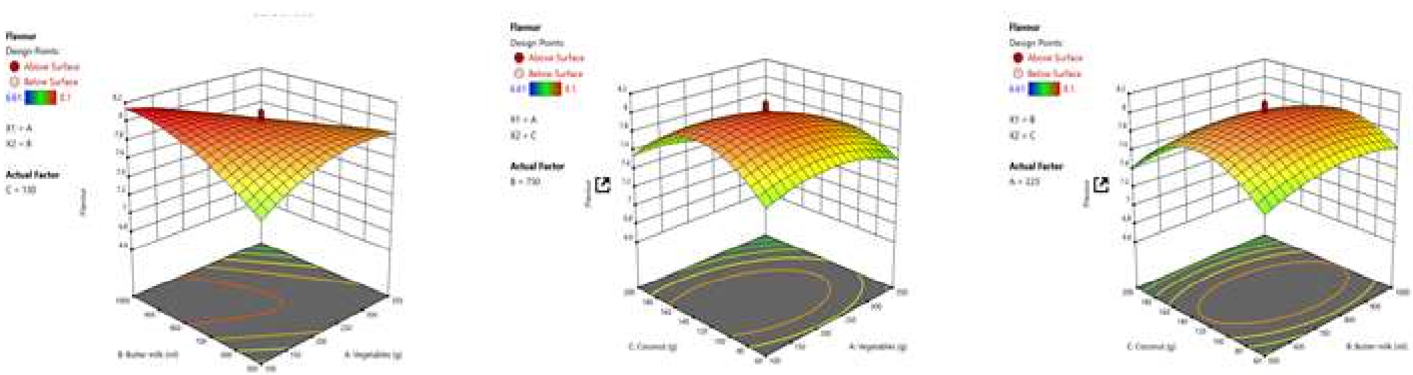

Fig. 2 (a-c) Response surface plot of the effects ingredients on flavour of Kaalan

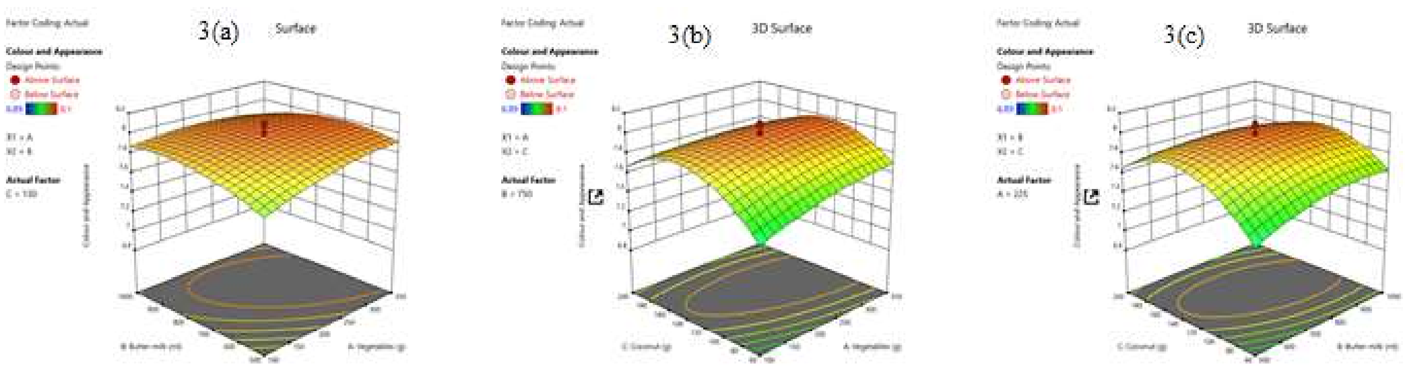

Fig. 3 (a-c) Response surface plot of the effects ingredients on colour and appearance of Kaalan

critical for maintaining the inherent properties of food products (Al Saqqa, 2022). Different steps in food processing, cooking, storage, and packaging, as well as the inherent characteristics of its ingredients, may change the overall flavour profile of food including reductions in intensity or the generation of undesirable flavour compounds. The flavour of fermented milk products is highly affected by the type of starter culture used and the extent of fermentation. In the preparation of optimized Kaalan the milk added with *Lim. fermentum* was incubated till the acidity reached one per cent lactic acid. In a similar study, dahi with one per cent titratable acidity yielded the high flavour score in Kadhi, a traditional fermented milk-based curry in India (Manohar and Balasubramanyam, 2007).

Effect on color and appearance

Judges initially assess colour and appearance as the primary sensory attributes. Colour holds a significant role in marketing of a product. Research has demonstrated that the visual presentation of a meal exerts influence on appetite modulation, ranging from appetite stimulation to suppression, thereby impacting the overall sensory experience and resulting in either pleasure or aversion (Mavrommatis et al. 2011). Consequently, the visual aesthetics of a food or beverage significantly affect its desirability and acceptance, shaping the anticipatory craving and receptiveness prior to any direct sensory contact. This principle underscores the adage that "we eat first with our eyes". The colour and appearance scores of the Kaalan ranged between 6.89 and 8.1 (Table 2). The response surface equation to predict the change in colour and appearance with different levels of the vegetable, buttermilk, and coconut is represented in Table 4. The maximum score was observed for standard run 15 which had a vegetable blend, buttermilk, and coconut content of 225, 750, and 130 grams respectively which had a bright mustard yellow colour. The samples with minimum scores were criticized for 'very dark' or 'very light' yellow colour. The regression coefficients and their significant levels for the model are given in Table 3. With R^2 value of 0.96, non-significant lack-of-fit and model F-value of 25.34, a significant ($p<0.05$) model was obtained. Adequate Precision (APV) was 15.53 which was highly desirable. Graphs 3a-3c illustrate the three-dimensional response plots obtained for the response. Among the various factors impacting colour and appearance, only the quantity of vegetables had a significant ($p<0.05$) influence, while the levels of buttermilk and coconut selected for testing showed no significant impact. However, interaction of different factors had significant negative influence on colour and appearance. Increasing the quantity of vegetables improve the colour and appearance of Kaalan. The

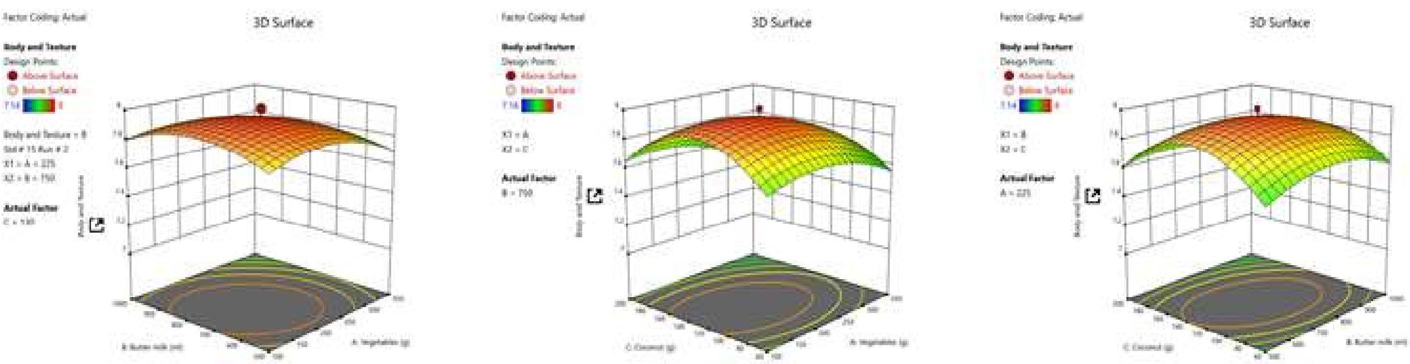

Fig. 4 (a-c) Response surface plot of the effects of ingredients on body and texture of Kaalan

Table 4. Regression equation to predict the changes in the sensory attribute at different levels of the independent factors in CCRD

Attribute	Response surface Equation	R^2
Flavour	8.00 – 0.1278*A + 0.0010*B – 0.1072*C – 0.3150*AB – 0.1100*AC – 0.0750*BC – 0.1709*A² – 0.1391*B² – 0.4131*C²	0.96
Colour and Appearance	7.98 + 0.0636*A + 0.0390*B + 0.0471*C - 0.0775*AB - 0.0950*AC - 0.0950*BC - 0.0610*A² - 0.1017*B² - 0.3332*C²	0.96
Body and Texture	7.95 - 0.0822*A - 0.0328*B - 0.0377*C - 0.0350*AB - 0.0350*AC - 0.0500*BC - 0.1185*A² - 0.1167*B² - 0.2617*C²	0.97
Overall acceptability	8.01 - 0.0316*A - 0.0112*B - 0.0653*C- 0.1563*AB - 0.1613*AC - 0.0488*BC - 0.1214*A² - 0.1780*B² - 0.3565*C²	0.93

A-Vegetable blend, B-Buttermilk, C-Coconut preferred colour of Kaalan is a bright mustard yellow and the vegetables used also contribute to the yellow colour. It negates the black/grey trace contributed by pepper. However, the white/creamy colour contributed by coconut and buttermilk reduced the brightness of Kaalan. Modha and Pal (2011) also reported that addition of pearl millet flour negatively affected the colour and appearance of the Rabadi-like fermented milk beverage. Our results align with this as the addition of ingredients affected the colour characteristics Kaalan.

Effect on body and texture

The sensory scores for body and texture ranged from 7.14 to 8. With 0.97 R^2, non-significant lack-of-fit and 33.33 model F-value a significant ($p<0.05$) model was obtained. APV was 16.77 which is highly desirable. The 3-D response graph and the regression equation are cited in Fig. 4a- 4c and in Table 4 respectively. The texture of Kaalan is defined by its thick body, which consists of firm yet well-cooked vegetable pieces enveloped in a concentrated, finely ground gravy. In sensory evaluation, the body and texture of a dish play a crucial role as they greatly influence the overall perception of quality and palatability, which is a fundamental consideration in assessing food products in general. Looking at the different factors affecting body and texture, only the quantity of vegetables had a highly significant ($p<0.01$) negative influence whereas the buttermilk and coconut had no influence at the levels selected for testing. Other researchers also reported similar trends. High levels of bengal gram increased the viscosity of kadhi and reduced the sensory score of the body and texture (Ghosh and Kulkarni, 1991; Manohar, 2005). Our results also align with this as increasing the quantity of vegetable increased the viscosity which had a negative effect on mouthfeel. However, in Rabdi-like fermented milk beverage, addition of pearl millet flour increased the consistency (Modha and Pal, 2011). The interaction of various ingredients seemed not to influence the body and texture of Kaalan.

Effect on overall acceptability

The aim of evaluating overall acceptability is to gauge how well a product meets consumer expectations and preferences. It serves as a valuable indicator of a product's market potential and consumer appeal. The overall acceptability assessment of Kaalan across various ingredient combinations is detailed in Table 2. Examination of model fit parameters revealed a coefficient of determination (R^2) of 0.93 and a model F-value ($p<0.05$) of 15.03, signifying the model's robustness. Furthermore, a high adequate precision value (11.31) and the absence of a significant lack of fit indicate the model's capability to predict response changes across factor levels. The 3-D graphical representation of the observations can be visualized from Fig. 5a - 5c. It is noteworthy that none of the individual ingredients exert a significant effect on the overall acceptability of Kaalan. However, the interactions between vegetable blend with both buttermilk and coconut exhibited a highly significant, negative influence on the overall acceptability of Kaalan.

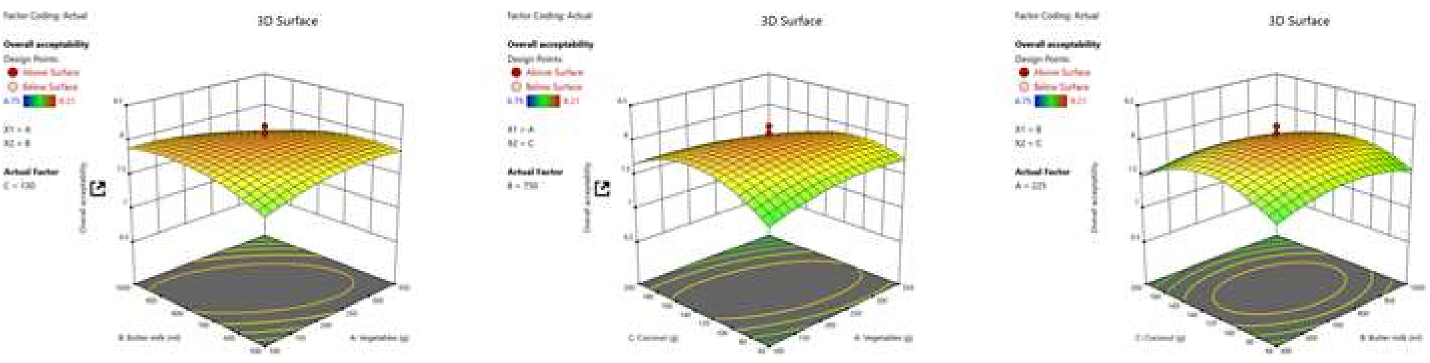

Fig. 5 (a-c) Response surface plot of the effects of ingredients on overall acceptability of Kaalan

Table 5: Constraints and criteria for the optimization of Kaalan

Constraints	Goal	Lower limit	Upper limit
A: Vegetable blend	In range	100	350
B: Buttrmilk	In range	500	1000
C:Coconut	In range	60	200
Flavour	Maximize	6.61	8.1
Colour and Appearance	Maximize	6.89	8.1
Body and Texture	Maximize	7.14	8
Overall acceptability	Maximize	6.75	8.21

Optimization of selected variables for Kaalan preparation

Optimization was performed to achieve the optimal combination of vegetable blend, buttermilk and coconut to be used for the preparation of Kaalan. Specific objectives and responses were identified for each factor, and diverse weights were assigned to refine the shape of their individual desirability functions. The sensory analysis scores were targeted for maximization and other factors were maintained within defined ranges throughout the optimization process (Table 5). RSM suggested levels of vegetables, buttermilk, and coconut as 194.97g, 748.09ml and 126.78g respectively. Additionally, the solution demonstrated a significantly high desirability value of 0.91. The optimal formulation, as determined by the software, underwent validation, revealing that the observed values did not exhibit statistically significant differences ($p > 0.05$) in comparison to the predicted values across all assessed attributes. The proposed formulation for the development of Kaalan was prepared and evaluated for sensory attributes. The sensory data obtained were compared with predicted values given by the software. Statistical verification was done using the t-test assuming equal variance and is represented in Table 6. The difference between the predicted scores (RSM) and the observed sensory scores were insignificant. Hence, the predicted level of factors for the optimum Kaalan formulation obtained holds good.

Analysis of Kaalan

The findings from the physicochemical analysis of the optimized Kaalan (on wet basis), in contrast to market samples, are detailed in Table 7. Market samples exhibited comparatively higher levels of most nutritional constituents, with the exception of curcumin. A significant increase in protein content ($p<0.05$) was observed in the market samples, potentially stemming from a higher usage of coconut and a reduced proportion of vegetables. The elevated fat content found in the market samples may be ascribed to the common practice of employing whole milk curd rather than buttermilk in the preparation of Kaalan by caterers and households. The carbohydrate content of optimized product was very low compared to market samples. The reported carbohydrate content of market samples represents the combined value of both carbohydrate and dietary fiber. Notably, the dietary fiber content of market samples was not assessed in this study. Hence, it is conceivable that the actual carbohydrate content could be lower than the reported figure. The energy value of Kaalan is very low compared to other products considering the low serving size of 20-25g. Kaalan can be considered as a low-calorie dietetic food. The optimized Kaalan had lower energy value compared to that of market sample due to the use of buttermilk which has low fat

Table 6: Comparison of predicted values and observed values for optimized Kaalan

Attributes	Predicted value	Observed value	t-value
Flavour	7.83±.08	8.12±0.08	1.981 ^{ns}
Colour and Appearance	7.98±.06	8.15±0.07	1.614 ^{ns}
Body and Texture	7.75±.04	8.11±0.12	2.411 ^{ns}
Overall Acceptability	7.9±0.09	8.17±0.05	2.364 ^{ns}

All observations are mean values of four replications with SE,
ns- non-significant ($p \geq 0.05$)

Table 7: Comparison of physico chemical properties of optimized Kaalan with market samples of Kaalan (on wet basis)

Attributes	Optimized Kaalan	Market samples of Kaalan	t-value
Protein (per cent)	3.49±0.005	6.34±0.59	4.856*
Fat (per cent)	7.12±0.07	9.31±1.42	1.538^{ns}
Carbohydrate (per cent)	9.95±0.08	11.28±0.75$^{\#}$	ND
Dietary Fiber (per cent)	4.84±0.22	ND	ND
Ash (per cent)	2.17±0.03	2.41±0.09	2.514^{ns}
Total solids (per cent)	28.36±.04	29.36±0.10	1.001^{ns}
Energy value (kcal/100g)	117.77±0.34	154.32±10.84	3.371*
pH	4.23±0.08	4.32±0.11	0.711^{ns}
Acidity (per cent lactic acid)	0.77±0.05	0.84±0.008	1.245^{ns}
Curcumin (ppm)	13.63±0.03	2.54±0.37	29.751**
L	60.67±0.19	61.95±0.14	5.374*
a	-0.19±0.09	2.88±1.66	1.839^{ns}
b	53.85±0.27	45.89±1.67	4.703*
Water activity	0.99±0.001	0.99±0.001	ND

Figures are mean ± standard error, *significantly different at $p < 0.05$, ** significantly different at $p < 0.01$, ND=not determined, $^{\#}$ Carbohydrate + dietary fiber content rather than full fat curd/yoghurt. It may also be due the use of high quantity of vegetables compared to that of most of the market samples. The curcumin content in the optimized Kaalan was significantly higher ($p<0.01$) compared to market samples. This distinction could be attributed to the incorporation of freshly powdered turmeric in the preparation of optimized Kaalan. Yewle et al. (2021) reported that prolonged storage of turmeric can lead to a reduction in curcumin content. The lower values in the market samples may be due to the use of packaged turmeric powders available in the market, which often undergo extended storage periods. The discrepancy may also be influenced by the moderated usage of turmeric powder in the preparation of market samples. In the examination of colour characteristics, it becomes evident that the 'L' value was significantly higher for market Kaalan whereas the 'b' value was significantly higher for optimized Kaalan ($p<0.05$). Herein, the 'L' value is indicative of lightness, and the 'b' value denotes yellowness. The optimized Kaalan had high 'b' value and high curcumin content. The 'b' value is positively correlated ($r=0.943$) to the curcumin content in Kaalan. Furthermore, the presence of a negative 'a' value suggests a subtle greenish undertone in the optimized Kaalan, whereas a positive 'a' value in the market sample signifies redness, likely arising from the inclusion of red chilli powder in its preparation (Divya et al. 2023).

Conclusion

Kaalan holds cultural and gastronomic significance, symbolizing the region's culinary heritage and fostering a sense of communal harmony during festive gatherings. Its preparation and consumption reflect the traditional culinary wisdom and cultural practices that have been passed down through generations in Kerala. The production of Kaalan was optimized using response surface methodology. The optimized Kaalan had 3.49 per cent protein, 7.12 per cent fat, 9.95 per cent carbohydrate, 4.84 per cent dietary fibre and 13.63 ppm curcumin. It exhibited 31 per cent reduction in energy value when compared to the Market sample. It had a high dietary fiber content due to the use of elevated levels of vegetables. This demonstrates that Kaalan is a functional food with low calories and lots of dietary fiber. The optimization and characterisation of Kaalan could lead to its large-scale industrial production and widespread acceptance. It is imperative to conduct both *in vitro* and *in vivo* digestion studies, to ascertain the bio-functionality of Kaalan,

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