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Research Article
Texture Profile of Groundnut Cake (*Kulikuli*) Produced from Three Varieties of Groundnut (*Arachis hypogaea* L.)

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Abstract
Background and Objective: The composition and processing parameters of *Kulikuli* assure the desired culinary qualities, while the feelings of individuals during chewing of *Kulikuli* are the important item reflecting its acceptability. Thus, this study optimized the processing conditions, groundnut variety (*Kampala*, *Kwanyamili*, *Gogokampala*), frying temperature (160-170°C) and frying time (1-3 min) for texture profiles of *Kulikuli* using the Taguchi technique. **Materials and Methods:** Different treatment combinations obtained by L_9 (3^3) of Taguchi orthogonal array were used to produce *Kulikuli*. The texture profile was measured using a food compression test with the aid of testometric material testing machine. **Results:** The values of hardness, springiness, adhesiveness, cohesiveness, chewiness, fracturability, gumminess, energy to break and stringiness varied from 159.82-321.83 N, 0.14-0.53, -0.01-0.39 Ns, 0.05-0.28, 1.41-32.23 N, 43.41-227.30 N, 10.42-54.79 N, 0.16-0.44 Nm and 2.23-3.08 mm, respectively. The processing combination that guarantees the best quality were established for each textural profile of the *Kulikuli* samples evaluated. The groundnut variety had the most significant influence on the quality of *Kulikuli* while time and temperature of frying follows, respectively. **Conclusion:** The results found in this study can be applied to industrial designs and operational guides that can guarantee softer texture, less adhesive and easy-to-chew *Kulikuli* for people of all age groups.

Key words: Texture profile, *Kulikuli*, groundnut, taguchi technique, process optimization, processing conditions, culinary properties

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Groundnut cake known as *Kulikuli* in Nigeria is a groundnut-based snack indigenous to the West coast of Africans. *Kulikuli* is simply regarded as the fried residue obtained after extracting oil from groundnut paste[1]. It has been reported to be rich in protein and crude fat similar to its parent material, groundnut[2,3]. Being a snack, it is consumed by all age ranges but more specifically by school-age children and the middle-aged. It is also used as a major ingredient in poultry feed formulation[4]. However, the texture of *Kulikuli* across Nigeria is relatively hard. On the contrary, the western countries' preference for relatively soft textured food materials that also maintain other desirable properties is yet to be ascertained with *Kulikuli* as a case study.

Food texture is about the perception of a foodstuff that originates in the structure of that product and how the product behaves when handled and eaten. It also includes the sensory properties perceptible using mechanical and tactile receptors from the mechanical, geometrical and surface properties of food[5]. The food texture, in concord with other sensory properties of foods (like appearance, taste and aroma), is one of the most important factors that consumers appreciate and enjoy in any food products[6]. *Kulikuli* is difficult to chew and swallow for most especially elderly people and children with milk teeth. This was due to the hard nature of this product. Therefore, to evaluate the ease of mastication, an Instron-type instrument that adopted a simple compression test has been commonly used to determine the firmness of food[5,7]. The maximum stress detected during this compression test is referred to as food firmness.

Notwithstanding the detection of its texture, Aletor and Ojelabi[2] reported that lack of adequate information on the composition and processing effects on the food value of *Kulikuli* is the major problem, rather than its had texture. Also, Koç *et al.*[6] reported that during processing the physical and chemical properties of food change dynamically and so does the perception of textural properties. Thus, the need to optimize some of its processing conditions. The processing conditions optimizations are usually done to have greater control over qualities, productivities and cost aspects of the processing Hussein *et al.*[8]. In line with this, the study adopted the Taguchi experimental plan that exposes all the process conditions to various levels of design parameters to optimize the processing conditions of *Kulikuli*.

MATERIALS AND METHODS

Study area: The study was carried out at the Department of Food Science and Technology, Food Processing Laboratory, Modibbo Adama University, Yola, from October, 2017-December, 2020.

Sample collection: Groundnut seeds of the *Kampala*, *Gogo Kampala*, *Kwanyamili* varieties were purchased from the local market in Hong, Adamawa State. The texture analyses were done with the aid of Testometric material testing machine at the Food Laboratory of National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria.

Experimental design: The experimental design technique of Genichi Taguchi that was devised specifically to improve the quality of Japanese manufactured goods in the post-war period in conjunction with Analysis of Variance (ANOVA) was used. The Taguchi orthogonal array was designed using Minitab version 16 software (Minitab, Inc. Coventry, UK) for three factors at three levels, having an array of L_9 (3×3) based on the outcome of the preliminary trial experiment. The data in Table 1 shows the outline of Taguchi experimental design L_9 (3×3) which gave nine experimental runs to evaluate the responses of the production of *Kulikuli*.

Sample preparation and production of *Kulikuli*: The production of *Kulikuli* was done as described by Emelike and Akusu[9] with slight modification (Fig. 1). The groundnut seeds were sorted to select wholesome ones and then milled into a smooth paste. Groundnut paste and additives were weighed using an electronic balance (10 kg×1 g digital kitchen electronic scale). A hundred grams (100 g) of the smooth paste was transferred into mixing bowls and 0.5 g of powdered dry pepper and 0.3 g of salt were added as seasoning. They were thoroughly mixed in the bowl and transferred to a properly clean chopping board. Vigorous kneading was applied then, the oil was extracted out of it. The mixture gradually became harder and sticky during the kneading process and oil was continually extracted. After which the paste was moulded into flat round shapes (1 cm diameter and 5 cm length) and fried using the oil extracted during the kneading process until a fairly brown colour was obtained under controlled temperature. The procedure was repeated for the other blends of groundnut paste following the experimental layout in Table 1. The produced *Kulikuli* samples were cooled a room temperature (25±1°C) for about 15-20 min and then keep in an air-tight container until when needed for further analysis.

Determination of texture profiles of *Kulikuli*: The *Kulikuli* samples were subjected to compressive force by probe up to

Table 1: Outline of Taguchi experimental design L_9 (3x3) for *Kulikuli* production

	Independent variables in coded form			Experimental variables in their natural units		
Experimental runs	A	B	C	Groundnut variety	Temperature (°C)	Time (min)
1	1	1	1	KA	160	3.00
2	1	2	2	KA	165	2.00
3	1	3	3	KA	170	1.00
4	2	1	2	KW	160	2.00
5	2	2	3	KW	165	1.00
6	2	3	1	KW	170	3.00
7	3	1	3	GK	160	1.00
8	3	2	1	GK	165	3.00
9	3	3	2	GK	170	2.00

KA: Kampala variety of groundnut, KW: Kwanyamili variety of groundnut and GK: Gogo Kampala variety of groundnut

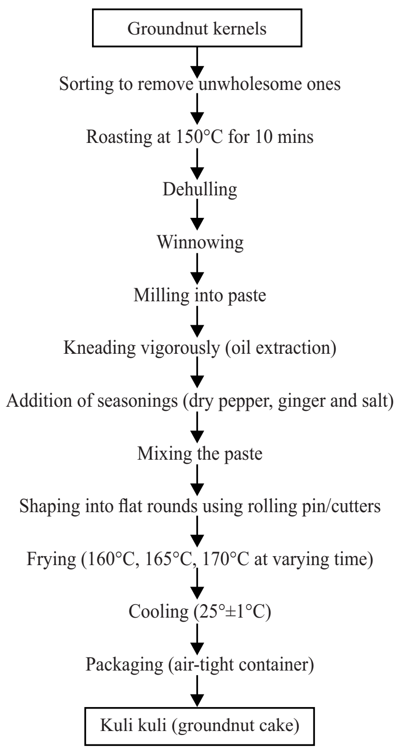

Fig. 1: Flow diagram showing the production of *Kulikuli*
Source: Adapted from Emelike and Akusu[9]

the distance of 0.50 mm two times resulting in two curves (Fig. 2). The condition-set up in the texture analyser for measuring textural properties was as follows: Test speed was 102 mm min^{-1}, preload test speed was 60.000 mm min^{-1}, posttest speed was 1.0 mm s^{-1}, the count was 2, deflection was 20% strain, preload (trigger) force was 0.50 N, break sensitivity was 0.20 N, acquisition rate was 200 pps and probe diameter was 100 mm. The following parameters: Hardness, springiness, adhesiveness, cohesiveness, chewiness, fracturability, gumminess, energy to peak and stringiness were generated from the force-deflection graph plotted by Texture Analyser. The testing was replicated a minimum of 3 times mean values for each parameter were calculated. Figure 2 depicted a typical curve obtained for the texture profile analysis.

Hardness was calculated as the peak force of the first compression of the product. The cohesiveness, which represents how well the product, withstands a second deformation relative to how it behaved under the first deformation was calculated as the ratio of the area under the second peak to the first peak[5]. Springiness that shows how well a product physically springs back after it has been deformed during the first compression was measured at the downstroke of the second compression, so the wait time between two strokes can be relatively important[5]. Springiness is measured by the distance of the detected height of the product on the second compression divided by the original compression distance. The chewiness was measured as a product of hardness, cohesiveness and springiness[10,11].

Process optimization using Taguchi technique: Taguchi optimization technique suggested that the production process or combination having the smallest variability is the optimal or best condition. This variability is determined by the signal-to-noise (S/N) ratio which represents quality characteristics for the observed data in the Taguchi method[12]. The signal-to-noise ratio is used as an index to evaluate the quality of the production processes. The 'signal' represents the desired value, the 'noise' represents the undesirable value and the signal to noise ratio expresses the scatter around the desired values. The experimental results obtained were then transformed into three types of S/N ratios namely, smaller-the-better, nominal-the-best and larger-the-better as shown in Eq. (1-3)[12]:

Nominal is the best characteristic

$$\frac{S}{N}=10\log\frac{\bar{y}}{sy^{2}} \tag{1}$$

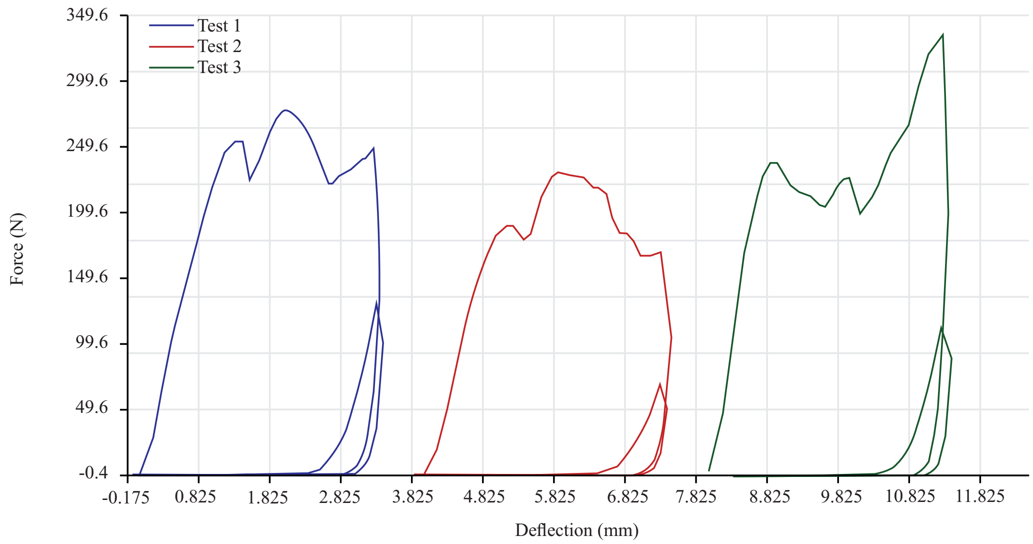

Fig. 2: Typical curve obtained for the texture profile analysis

Smaller is the better characteristic

$$\frac{S}{N}=-10\log\frac{1}{n}\left(\sum y^2\right) \tag{2}$$

Larger is the better characteristic

$$\frac{S}{N}=-10\log\frac{1}{n}\left(\sum\frac{1}{y^2}\right) \tag{3}$$

Where:

$\bar{y}$ = Average response data
Sy^2 = Variation of y and n in the number of treatments
y = Response data

For each type of the characteristics of the above S/N ratio transformation, the average mean of the response for each level of the factors as shown in the experimental table was calculated. Also, the average signal to noise ratio (S/N ratio) was calculated for each level of all the factors. The smaller the better equation was used for calculating the signal to noise ratio of moisture contents, fat contents, bending, compression, hardness, springiness, gumminess and springiness. The nominal is the best was used for calculating the signal to noise ratio of adhesiveness, cohesiveness, chewiness, fracturability and energy to break. While the larger the better equation was used for calculating the signal to noise ratio of appearance, taste, colour, aroma and overall acceptability.

Statistical analysis: The experimental data obtained were analyzed using a statistical package for social sciences (SPSS) software (SPSS 20.0 for Windows, SPSS Inc., Chicago, IL, USA) and the results were expressed as Mean±SE. The significance of the difference between the means was determined using Duncan's Multiple Range Test and the differences were considered to be significant at $p<0.05$.

RESULTS AND DISCUSSION

Effect of the processing conditions on the hardness texture of *Kulikuli*: The influence of the processing conditions on the texture profile of *Kulikuli* is presented in Table 2. The hardness of the *Kulikuli* samples ranged from 159.82 N to 321.83 N which showed that experimental run 6 (KW, 170°C, 3 min) had the least value while experimental run 3 (KA, 170°C, 1 min) had the highest value. The response means S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to groundnut variety as the highest delta value follow by frying time (rank 2nd) and temperature of frying (rank 3rd) which is the lowest delta value. This shows that the groundnut variety is the most significant processing parameter controlling the hardness of the *Kulikuli* sample. While the time and temperature of frying follow respectively. Similar observations were reported by Hamid *et al.*[13] and Bakare *et al.*[11] that the softness and hardness of cooked beans are determined by the cowpea variety and time of cooking. It was also observed that a short frying time corresponds to softer products.

Table 2: Influence of the processing conditions on the texture profile of Kuli kuli

Experimental Runs	Hardness (N)	Springiness	Adhesiveness (N.s)	Cohesiveness	Chewiness (N)	Fracturability (N)	Gumminess (N)	Energy to Break (N.m)	Stringiness (mm)
KA, 160°C, 3 min	281.43 ± 30.29^{ab}	0.33 ± 0.02^{bc}	0.39 ± 0.38^{a}	0.09 ± 0.01^{bc}	8.37 ± 1.34^{b}	227.30 ± 19.19^{a}	25.88 ± 4.83^{ab}	0.44 ± 0.13^{a}	2.90 ± 0.03^{ab}
KA, 165°C, 2 min	264.72 ± 28.91^{ab}	0.24 ± 0.04^{bcd}	-0.01 ± 0.00^{a}	0.05 ± 0.02^{c}	4.11 ± 2.57^{b}	196.38 ± 18.66^{ab}	15.07 ± 7.49^{b}	0.31 ± 0.10^{a}	2.41 ± 0.05^{cd}
KA, 170°C, 1 min	321.83 ± 64.76^{a}	0.39 ± 0.09^{ab}	-0.01 ± 0.00^{a}	0.13 ± 0.04^{bc}	21.21 ± 12.04^{ab}	224.52 ± 26.74^{a}	46.90 ± 22.23^{ab}	0.36 ± 0.16^{a}	2.23 ± 0.16^{d}
KW, 160°C, 2 min	220.77 ± 50.44^{ab}	0.38 ± 0.06^{ab}	-0.01 ± 0.00^{a}	0.18 ± 0.03^{ab}	15.75 ± 6.34^{ab}	144.73 ± 55.17^{abcd}	38.82 ± 10.07^{ab}	0.27 ± 0.09^{a}	2.23 ± 0.10^{d}
KW, 165°C, 1 min	246.84 ± 39.20^{ab}	0.18 ± 0.03^{cd}	-0.01 ± 0.00^{a}	0.07 ± 0.02^{bc}	3.17 ± 1.69^{b}	169.52 ± 48.32^{abc}	15.82 ± 6.97^{b}	0.20 ± 0.03^{a}	2.51 ± 0.03^{cd}
KW, 170°C, 3 min	159.82 ± 14.82^{b}	0.14 ± 0.03^{d}	-0.01 ± 0.00^{a}	0.07 ± 0.01^{bc}	1.41 ± 0.29^{d}	43.41 ± 43.41^{d}	10.42 ± 0.82^{b}	0.16 ± 0.05^{a}	2.57 ± 0.04^{bcd}
GK, 160°C, 1 min	244.41 ± 17.98^{ab}	0.36 ± 0.02^{ab}	-0.01 ± 0.00^{a}	0.15 ± 0.03^{bc}	13.09 ± 3.48^{ab}	145.86 ± 4.95^{abcd}	35.87 ± 9.05^{ab}	0.39 ± 0.02^{a}	2.70 ± 0.03^{bc}
GK, 165°C, 3 min	202.28 ± 7.81^{ab}	0.53 ± 0.11^{a}	-0.01 ± 0.00^{a}	0.28 ± 0.08^{a}	32.23 ± 12.27^{a}	61.04 ± 31.04^{cd}	54.79 ± 15.36^{a}	0.38 ± 0.04^{a}	2.23 ± 0.27^{d}
GK, 170°C, 2 min	206.88 ± 33.62^{ab}	0.15 ± 0.02^{d}	0.01 ± 0.00^{a}	0.08 ± 0.02^{bc}	2.52 ± 0.92^{c}	91.60 ± 6.71^{bcd}	15.72 ± 3.58^{b}	0.32 ± 0.06^{a}	3.08 ± 0.05^{a}

Means values in the same columns bearing the same superscript are not signicantly different ($p<0.05$), KA: Kampala, KW: Kwanyamili and GK: Gogo Kampala

The smaller the S/N ratio the better was considered to optimize the hardness of the *Kulikuli* produced and the corresponding main effect plot for the S/N ratio is shown in Fig. 3a-c. The significance of each processing parameter and the optimal processing combinations was judged by the inclination of this plot. The optimal process parameter combination is the one that yields the highest S/N ratio value. Thus, the use of KA variety along with 1 min frying time at 170°C frying temperature is the best processing combination that can guarantee the best hardness texture within the experimental domain considered in the present study.

Effect of the processing conditions on the springiness texture of *Kulikuli*: Springiness organoleptically depicts how well a product physically springs back after it has been deformed during the first compression and has been allowed to wait for the target wait time between strokes[11]. The springiness of the *Kulikuli* samples ranged from 0.14-0.53 which showed that experimental run 6 (KW, 170°C, 3 min) had the least value while experimental run 8 (GK, 165°C, 3 min) had the highest value. The response means S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to the temperature of frying with the highest delta value followed by groundnut variety (rank 2nd) and time of frying (rank 3rd) which had the lowest delta value. This shows that the temperature of frying is the most significant processing parameter controlling the hardness of the *Kulikuli* sample. While the groundnut variety and time of frying follow, respectively.

The smaller the S/N ratio the better was considered to optimize the springiness of the *Kulikuli* produced and the corresponding main effect plot for the S/N ratio is shown in Fig. 4a-c. The KW variety along with 2 min frying time at 170°C frying temperature had the highest S/N ratio value. Thus, this is the best processing combination that can guarantee the best springiness texture within the experimental domain considered in the present study.

Effect of the processing conditions on the adhesiveness texture of *Kulikuli*: The adhesiveness of the *Kulikuli* samples ranged from -0.01-0.39 Ns. The values were statistically not significant ($p>0.05$). The negative values obtained indicate that the *Kulikuli* samples are not sticky. Thus, it requires little or no force to overcome the sticky forces between the sample and the probe. Bakare *et al.*[11] reported that adhesion is measured as the negative work between the two cycles, however, in many instances, the product has stuck to the

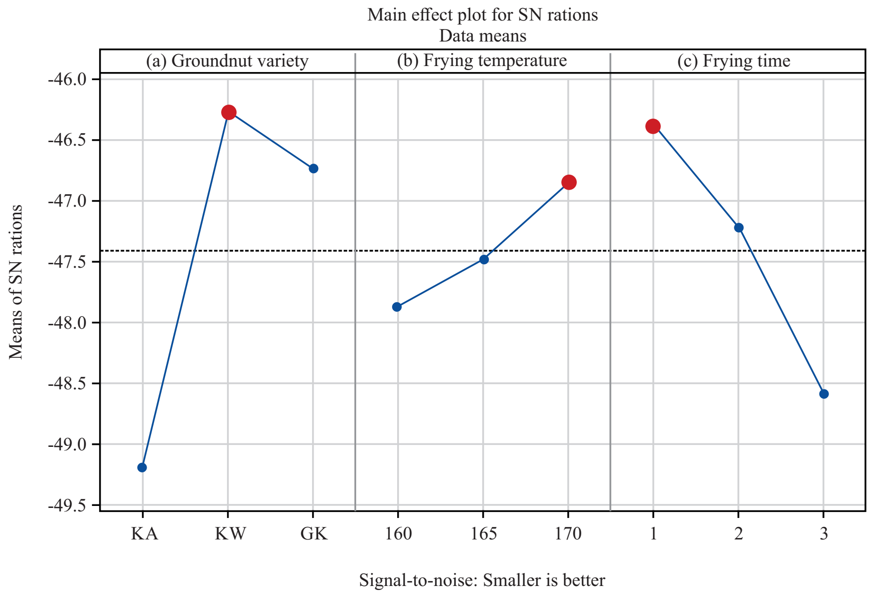

Fig. 3(a-c): Main effect plot for a signal to noise (S/N) ratio on the hardness of *Kulikuli*

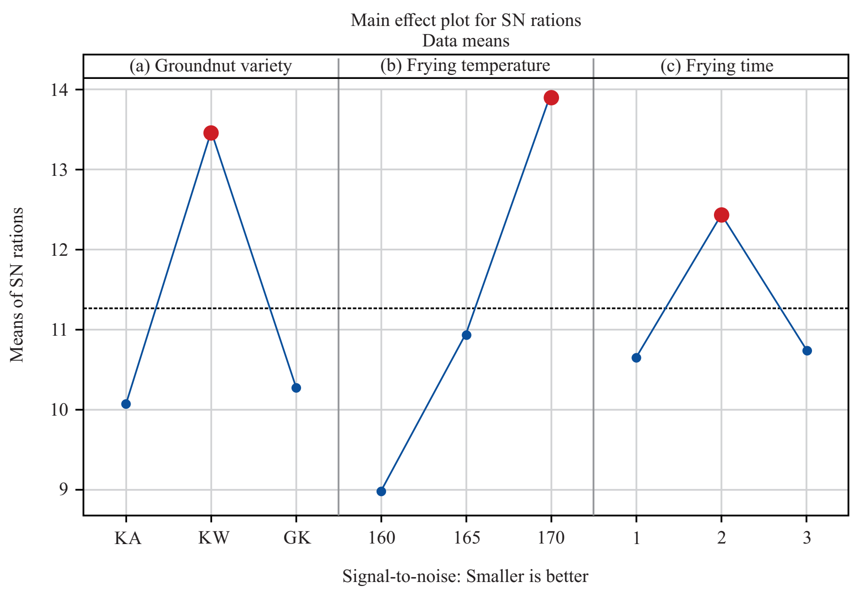

Fig. 4(a-c): Main effect plot for the signal to noise (S/N) ratio on the springiness of *Kulikuli*

probe and does not separate when the highest point between the two cycles is just back to the original product height thereby giving negative values. Also, these lower values of adhesiveness obtained may imply that the *Kulikuli* samples may not have been overcooked to the point of stickiness. Due to these negative values obtained, the S/N ratio is undefined.

Effect of the processing conditions on the cohesiveness texture of *Kulikuli*: The cohesiveness of *Kulikuli* reflects the strength of the internal bonds binding the chewed food particles together thus suggesting how well the *Kulikuli* withstands a second deformation relative to its resistance under the first deformation. The cohesiveness of the *Kulikuli* samples ranged from 0.05-0.28 indicating that experimental run 2 (KA, 165°C, 2 min) had the least value while experimental run 8 (GK, 165°C, 3 min) had the highest value. The response means S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to groundnut variety with the highest delta value followed by the temperature of frying (rank 2nd) and time of frying (rank 3rd) which had the lowest delta value. This shows that the groundnut variety is the most significant processing parameter controlling the cohesiveness of the *Kulikuli* sample. While the temperature and time of frying follow, respectively. The nominal S/N ratio the better was considered to optimize the cohesiveness of the *Kulikuli* produced. Therefore, the average value of cohesion was considered as the optimum value, which corresponds to GK variety along with 3 min frying time at 160°C frying temperature. Thus, this is the best processing combination that can guarantee the best cohesiveness texture within the experimental domain considered in the present study.

Effect of the processing conditions on the chewiness texture of *Kulikuli*: Chewiness connotes the energy required to chew a solid food till it is ready for swallowing. It is sometimes estimated as the product of hardness, cohesiveness and elasticity[14]. The chewiness of the *Kulikuli* samples ranged from 1.41-32.23 which showed that experimental run 6 (KW, 170°C, 3 min) had the least value while experimental run 8 (GK, 165°C, 3 min) had the highest value. The response means S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to groundnut variety with the highest delta value followed by the time of frying (rank 2nd) and temperature of frying (rank 3rd) which had the lowest delta value. This shows that the groundnut variety is the most significant processing parameter controlling the chewiness of the *Kulikuli* sample. Therefore, the average value of chewiness was considered as the optimum value, which corresponds to GK variety along with 3 min frying time at 165°C frying temperature. Thus, this is the best processing combination that can guarantee the best chewiness texture within the experimental domain considered in the present study.

Effect of the processing conditions on the fracturability texture of *Kulikuli*: Fracturability is the force required to crack the *Kulikuli* sample, which is the first bite force through the *Kulikuli* at the commencement of the chewing process[15]. The fracturability of the *Kulikuli* samples ranged from 43.41-227.30 N which showed that experimental run 6 (KW, 170°C, 3 min) had the least value while experimental run 1 (KA, 160°C, 3 min) had the highest value. The response means S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to groundnut variety with the highest delta value followed by the time of frying (rank 2nd) and temperature of frying (rank 3rd) which had the lowest delta value. This shows that the groundnut variety is the most significant processing parameter controlling the fracturability of the *Kulikuli* sample. While the time and temperature of frying follow, respectively. The average value of fracturability was considered as the optimum value, which corresponds to KA variety along with 1 min frying time at 160°C frying temperature. Thus, this is the best processing combination that can guarantee the best fracturability texture within the experimental domain considered in the present study.

Effect of the processing conditions on the gumminess texture of *Kulikuli*: Gumminess is conceived as the energy required to disintegrate a semi-solid food to make it ready for swallowing[15]. The gumminess of the *Kulikuli* samples ranged from 10.42-54.79 N which showed that experimental run 6 (KW, 170°C, 3 min) had the least value while experimental run 8 (GK, 165°C, 3 min) had the highest value. The response means S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to groundnut variety with the highest delta value followed by the temperature of frying (rank 2nd) and time of frying (rank 3rd) which had the lowest delta value. This shows that the groundnut variety is the most significant processing parameter controlling the hardness of the *Kulikuli* sample. While the temperature and time of frying follow respectively. The smaller the S/N ratio the better was considered to optimize the gumminess of the *Kulikuli* produced and the corresponding main effect plot for the S/N ratio is shown in Fig. 5a-c. The KW variety along with 2 min frying time at 170°C frying temperature had the highest S/N ratio value. Thus, this is the best processing combination that can guarantee the best gumminess texture within the experimental domain considered in the present study.

Effect of the processing conditions on the energy to break texture of *Kulikuli*: The energy to break the *Kulikuli* samples ranged from 0.16-0.44 Nm. The values were statistically not significant (p>0.05) but they varied from one sample to the other. The response means the S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to groundnut variety with the highest delta value followed by the temperature of frying (rank 2nd) and of time frying (rank 3rd) which had the lowest delta value. This shows that the groundnut variety is the most significant processing parameter controlling the energy required to break of *Kulikuli* sample. While the temperature and time of frying follow respectively. The nominal S/N ratio the better was considered to optimize the energy required to break the *Kulikuli* sample. Since our target is to have optimum breaking energy for the *Kulikuli* samples. Therefore, the

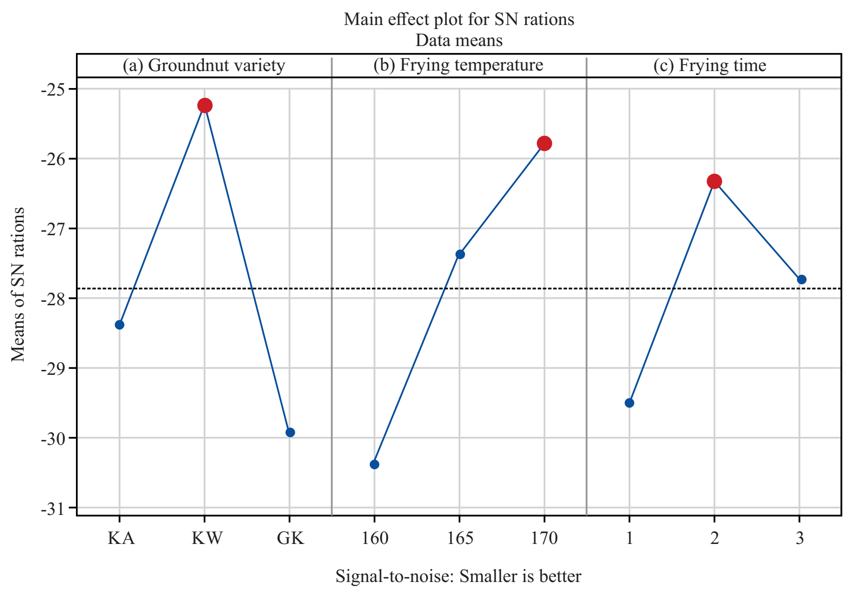

Fig. 5(a-c): Main effect plot for the signal to noise (S/N) ratio on the gumminess of *Kulikuli*

Table 3: Response table for means signal to noise (S/N) ratio for the texture profile of *Kulikuli* using Taguchi techniques

	Groundnut variety	Frying temperature	Frying time	Groundnut variety	Frying temperature	Frying time
	Hardness (smaller is better)			**Fracturability (nominal is best)**		
Level 1	-49.2	-47.88	-48.59	216.07	172.63	179.97
Level 2	-46.27	-47.47	-47.22	119.22	142.32	144.24
Level 3	-46.73	-46.85	-46.39	99.5	119.84	110.58
Delta	2.93	1.03	2.19	116.57	52.79	69.38
Rank	1st	3rd	2nd	1st	3rd	2nd
	Springiness (smaller is better)			**Gumminess (small is better)**		
Level 1	10.14	8.97	10.68	-28.42	-30.38	-29.5
Level 2	13.58	11.04	12.49	-25.37	-27.44	-26.42
Level 3	10.27	13.98	10.83	-29.93	-25.9	-27.8
Delta	3.44	5.01	1.81	4.56	4.47	3.08
Rank	2nd	1st	3rd	1st	2nd	3rd
	Cohesiveness (nominal is best)			**Energy to break (nominal is best)**		
Level 1	0.09	0.14	0.11	0.37	0.37	0.32
Level 2	0.1	0.13	0.11	0.21	0.29	0.3
Level 3	0.17	0.09	0.14	0.36	0.28	0.33
Delta	0.08	0.05	0.03	0.16	0.09	0.03
Rank	1st	2nd	3rd	1st	2nd	3rd
	Chewiness (nominal is best)			**Stringiness (small is better)**		
Level 1	11.23	12.4	12.49	-7.95	-8.29	-7.86
Level 2	6.78	13.17	7.46	-7.71	-7.52	-8.13
Level 3	15.94	8.34	14	-8.46	-8.31	-8.13
Delta	9.17	8.38	6.55	0.74	0.79	0.27
Rank	1st	3rd	2nd	2nd	1st	3rd

Level 1: Kampala variety, 160°C frying temperature and 3 min frying time, level 2: Kwanyamili variety, 165°C frying temperature and 2 min frying time and level 3: Gogo Kampala variety, 170°C frying temperature and 1 min frying time

average value of energy required to break obtained was considered as the optimum value, which corresponds to KA variety along with 3 min frying time at 160°C frying temperature. Thus, this is the best processing combination that can guarantee the best breaking energy within the experimental domain considered in the present study.

Effect of the processing conditions on the stringiness texture of *Kulikuli*: Stringiness is originally called "Elasticity", which is the rate at which a deformed sample returns to its original size and shape of the measured stretched distance of the samples when pulled from the area in which it rests during the test[15]. The stringiness of the *Kulikuli* samples ranged from

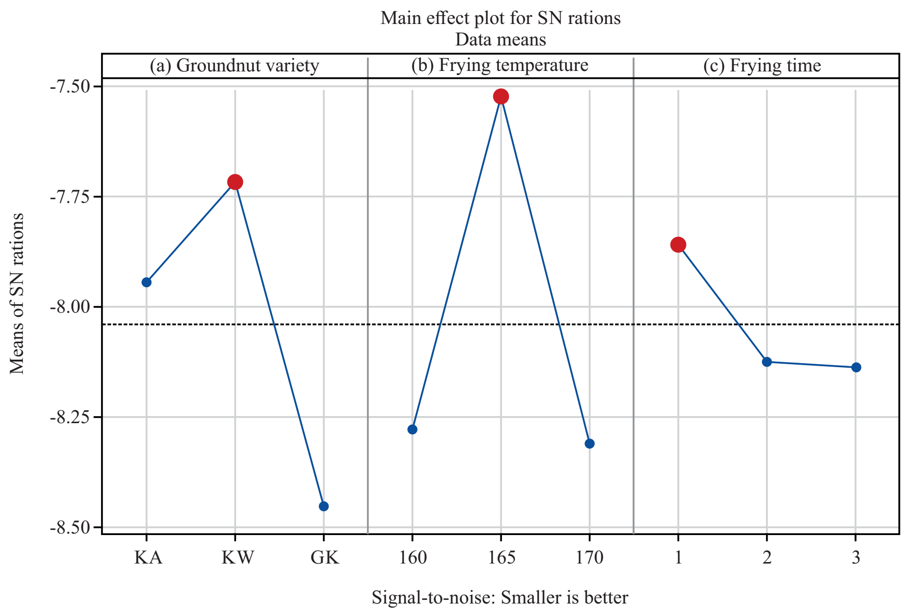

Fig. 6(a-c): Main effect plot for the signal to noise (S/N) ratio on the stringiness of *Kulikuli*

2.23-3.08 mm. The values were statistically not significant (p>0.05) within the variety however, they were significant (p<0.05) between the variety. The response means the S/N ratio for each level of the controlling factors is shown in Table 3. From the response mean S/N ratio, rank 1st is assigned to a temperature of frying with the highest delta value followed by groundnut variety (rank 2nd) and time of frying (rank 3rd) which had the lowest delta value. This shows that the temperature of frying is the most significant processing parameter controlling the hardness of the *Kulikuli* sample. While the groundnut variety and time of frying follow, respectively. The smaller the S/N ratio the better was considered to optimize the gumminess of the *Kulikuli* produced and the corresponding main effect plot for the S/N ratio is shown in Fig. 6a-c. The KW variety along with 1 min frying time at 165°C frying temperature had the highest S/N ratio value. Thus, this is the best processing combination that can guarantee the best springiness texture within the experimental domain considered in the present study.

CONCLUSION

It may be concluded that the processing conditions affect the textural profile of *Kulikuli*. The processing combination that guarantees the best quality were established for each textural profile of the *Kulikuli* samples evaluated. Groundnut variety significantly affects the hardness, cohesiveness, chewiness, fracturability, gumminess and breaking energy of the *Kulikuli* samples. On the other hand, the drying temperature significantly affects the springiness and stringiness of the *Kulikuli* samples. The results can be applied to industrial designs and operational guides that can guarantee softer texture, less adhesive and easy-to-chew *Kulikuli* for people of all age groups.

SIGNIFICANCE STATEMENT

This study discovers the processing combination that guarantees the best quality for each textural profile of the *Kulikuli* samples evaluated. The groundnut variety had the most significant influence on the quality of *Kulikuli* while time and temperature of frying followed, respectively. The information reported herein can benefit industrial designs and operational guides that can guarantee softer texture, less adhesive and easy-to-chew *Kulikuli* for people of all age groups. This study will help the researcher uncover the critical areas of the processing combination that affected the textural profile of the *Kulikuli* samples that many researchers could not explore. Thus a new theory on the textural profile of *Kulikuli* may be arrived at.

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