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Mixing as a Source of Variability in Ga-Kenkey

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Abstract
Aflata mixing process is one of the most tedious unit operations in the traditional Ga-*kenkey* production process, because it is typically done manually. As a result, there are variations in *kenkey* produced even by the same processor. Consequently it is difficult to produce *kenkey* with consistent quality on a large scale to meet the demands of consumers. The objective of this research was to assess the effect of *aflata* mixing processes as causes of variability in Ga-*kenkey*.
Laboratory experiments were done by varying *aflata* mixing ratio, and mixing time to assess the effects of these parameters on physical characteristics and consumer acceptability of Ga-*kenkey*.
The study identified *aflata* mixing as causes of variability in Ga-*kenkey*. The indices of variability include texture, *aflata* mixing ratio, and mixing time (extent of mixing). These indices affect the physical characteristics, consumer perception and acceptability of the final product. This finding would help Ga-*kenkey* processors to produce consistent product.
Keywords: *aflata*, *Ga-kenkey,*texture, mixing

1. Introduction

Kenkey is a sourdough dumpling from the Akan, Ga and Ewe inhabited regions of West Africa, usually served with a soup, stew, or sauce (Christian, 1966; Amoa and Muller, 1975; Dovlo, 1975). There are different types of *kenkey*, but the dominant types are the Ga-*kenkey* (*komi*) produced by the Gas in the Greater Accra region and the Fanti-*kenkey* (*dokono*) produced by the Fantis in the Central and Western regions (Muller, 1970; Halm et al., 2004). The types vary in the processing method used (Kordylas, 1990). Both are produced by the fermentation of maize dough into sour dough that is subsequently cooked, wrapped in maize husks or plantain leaves (Halm et al., 2004). Ga-*kenkey* processing is usually carried out by females who produce the *kenkey* as a subsidiary occupation.

During the preparation of Ga-*kenkey* one part of the fermented dough is cooked while strirring constantly and vigorously. This half is called *aflata*. *Aflata* is reported to act as a binding agent when mixed with uncooked fermented dough and enables the product to be molded into balls and other shapes (Sefa-Dedeh and Plange, 1989). The *aflata* is then combined with uncooked dough and mixed. The ratio of *aflata* mixed with uncooked dough depends on the preference of the consumer. During mixing of the cooked dough (*aflata*) with the non-cooked dough, the processors depend more on subjective rather than empirical measures for control. Degree of mixing is determined by visual examination and experience, rather than by empirically derived measures for determining and controlling mixing homogeneity. Since the degree of mixing of the *aflata* with raw dough affects the final *kenkey* quality (Amponsah, 2010), there are bound to be variations in quality of Ga-*kenkey* from the same producer and /or even in the same batch if the degree of mixing is determined only by hunch and experience.

Another aspect of mixing with potential impact on quality variability of Ga-*kenkey* is the ratio of cooked dough (*aflata*) to non cooked dough. Processors use different mixing ratios of *aflata* and raw dough in Ga-*kenkey* production, and depend largely on their experience and judgment to determine whether the mixture is homogenous enough. It is important to determine how the degree of mixing, and mixing ratios affect the quality of Ga-*kenkey*.

2. Materials and Method

The fermented corn dough and *aflata* were used in this study. The *aflata* and fermented dough were obtained from an experienced Ga-*kenkey* producer on Legon campus.

2.1 Degree of mixing

During the preparation of *aflata*, salt (sodium chloride) is normally added which increases the conductivity of the dough. On the other hand, raw corn dough to which no salt is added will have low conductivity. The degree of mixing could be determined by measuring the electrolyte conductivity with mixing time. Ten samples of mixed *aflata* and raw corn dough were taken from different locations of the mixing after every five minutes as mixing proceeded. Three producers were visited and used in this study. Each of the producers was visited twice for the collection of the samples. Mixing of *aflata* and raw corn dough obtained separately from the producers was also done in the laboratory using a 4.6 L Kenwood food processor for durations 1, 2, 3, 4, 5, and 6 minutes. Conductivity of each sample was determined by using a hand held pH/Conductivity meter (OAKTON deluxe waterproof pH/Conductivity meter kit, model No. 35630-62). The standard deviation of the mean conductivity of ten samples from each time interval or *kenkey* processor was calculated as a measure of the degree of mixing using equation 1 given by Earle (1983).

$$s^2 = \frac{1}{n}[(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \cdots + (x_n - \bar{x})^2] \qquad [1]$$

Where
s is the standard deviation
n is the number of samples
$x_1, x_2, \ldots x_n$ are fractional compositions of x in 1, 2,…n samples
x bar is the average fractional composition of component x in the whole mixture

2.2 Combine effect of mixing ratio and time on kenkey quality

Aflata and raw dough were obtained from an experienced Ga-*kenkey* producer. To investigate the effect of degree of mixing on variability of Ga-*kenkey* quality, raw dough and *aflata* were mixed in the laboratory at varying times using the ratios of 1:1, 1:2, and 2:3, and the standard deviations of the means of dough conductivity of salt determined. Each of mixture of the *aflata* and raw corn dough weighed 800g.The resulting mixtures were sent to the producer from whom the *aflata* and raw dough was taken to select which of the mixtures could be easily moulded. Hence mixtures obtained by mixing at times 2, 3, and 4 minutes were chosen and moulded into balls for cooking into kenkey. Nine Ga-*kenkey* samples were prepared using the mixing ratios and mixing time as above.

2.3 Sensory Analysis

Nine Ga-*kenkey* samples were prepared using the mixing ratios and mixing time as above. Traditionally prepared Ga-*kenkey* from the same producer from whom the raw dough and *aflata* were obtained was added. Fifteen sensory panelists were recruited randomly from University of Ghana campus. The panelists were people who are regular consumers of Ga-*kenkey* and familiar with characteristics of Ga-*kenkey*. A balanced incomplete block design ($t = 10$, $r = 6$, $b = 15$, $k = 4$, $\lambda = 2$, $E = 0.83$, type III) as described by Cochran and Cox (1957) was used to assign 10 samples to 15 panelists. This design was used because an individual consumer would find it increasingly difficult to evaluate as many as 10 different samples. This design allowed each consumer to evaluate four samples out of ten. Samples were presented to consumers in disposable plates coded with three-digit random numbers. Water was provided for each consumer to use during the test to rinse their mouths and reduce any residual effect between samples. Consumers were asked to evaluate the samples based on color, taste, smell, smoothness, hardness, and overall acceptance using a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely) (Peryam and Pilgrim, 1957; Prinyawiwatkul et al., 1997). The work and ballot sheets used in this analysis are shown in appendix 1.

2.4 Texture Profile analysis

Texture profile analysis (TPA) of the ten samples was determined using a Stable Micro System texture analyzer model TA-XT2i (Stable Micro System, Texture Technologies Corp., White Plains, NY) as described by Beleia et al (2004). The samples were compressed to 50% of initial height using two compression cycles with constant crosshead velocity of 5mm/s using a compression plate (75 mm diameter, aluminum). The compression was repeated twice to generate a force-time curve from which hardness (height of first peak) and springiness (ratio between recovered height after the first compression and the original *kenkey* height) was determined. The negative area of the curve during retraction of the probe was termed adhesiveness. Cohesiveness was calculated as the ratio between the area under the second peak and the area under the first peak. Gumminess was determined by multiplying hardness and cohesiveness. Chewiness was derived from gumminess and springiness and was obtained by multiplying these two. Ten repeated measurements were performed for each sample and their average was taken.

2.4 Statistical analysis

The data obtained from laboratory analyses were subjected to analysis of variance (ANOVA). Pearson correlation coefficients(r) for the relationships between sensory and textural hardness properties was also calculated using Statistical Software for Social Scientists version 16.0

3. Results and Discussion

3.1 Mixing process in Ga *kenkey* production as Source of Variability

A very important unit operation in Ga-*kenkey* production is the mixing of *aflata* and the raw, non-cooked dough.

The extent to which mixing is done has effect on the quality of the final product. Since salt (Sodium chloride) is added to the *aflata* during its preparation, the extent to which mixing is achieved was followed by measuring the conductivity of salt in several randomly obtained samples from the *aflata* and raw dough mix. The standard deviations of the conductivity of *aflata*- raw dough mixture from three producers on two different visits and that obtained from mixing in a food processor after every one minute up to six minutes are shown in figures 1, 2 and 3.

The degree of mixing for the three producers was significantly different for each producer, and for each visit. There was improvement in degree of mixing using food processor with increasing time until six minutes. During mixing of *aflata* with raw dough the producers do not put in place measures to check when mixing is thoroughly done. Rather they use their experience and judgment to determine when mixing was complete. This results in variation in mixing on the two occasions for each producer. This is in agreement with findings of Amponsah (2010), and Ackom-Quayson (1992) where they reported that inadequate mixing is one of the causes of variability in *kenkey* as jelly-like patches and soft spots may be found in the mixture. Results from mixing with a kenwood food processor suggest that the degree of mixing could be improved by increasing mixing time. Thus the principle of kenwood food processor could be adapted to design a mixer to obtain final product that is consistent in quality. This would relieve the producers of tedium and the stress they have to go through to mix the *aflata* and the raw dough.

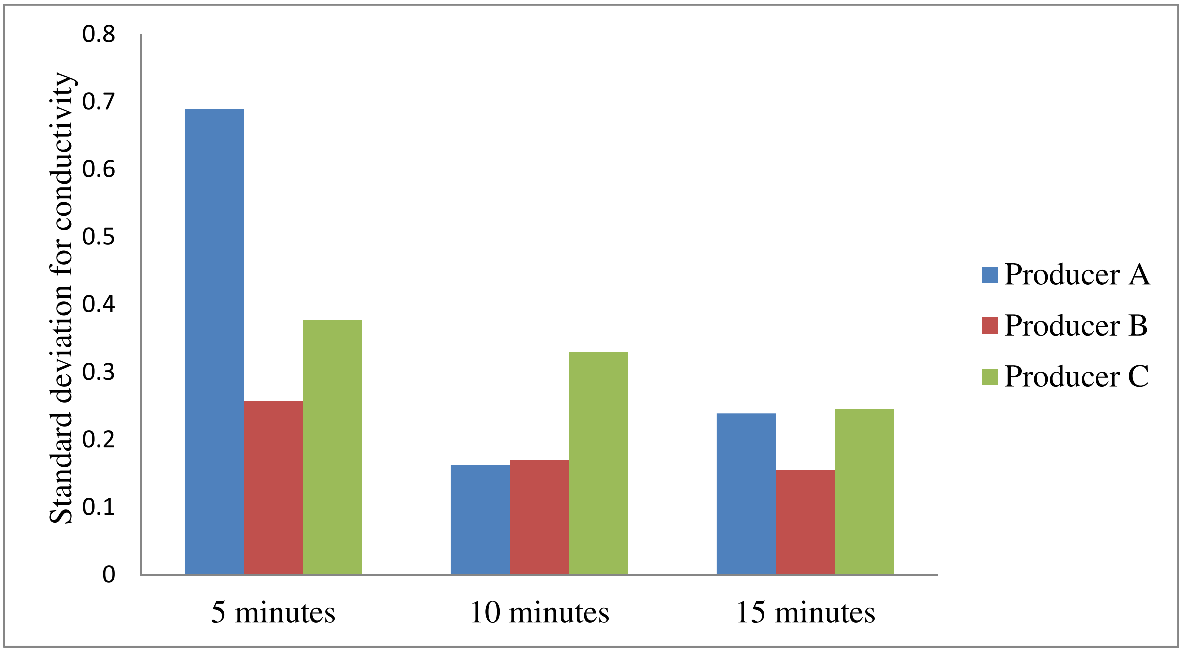

Figure 1: Variation of standard deviation of conductivity of salt with time-day 1

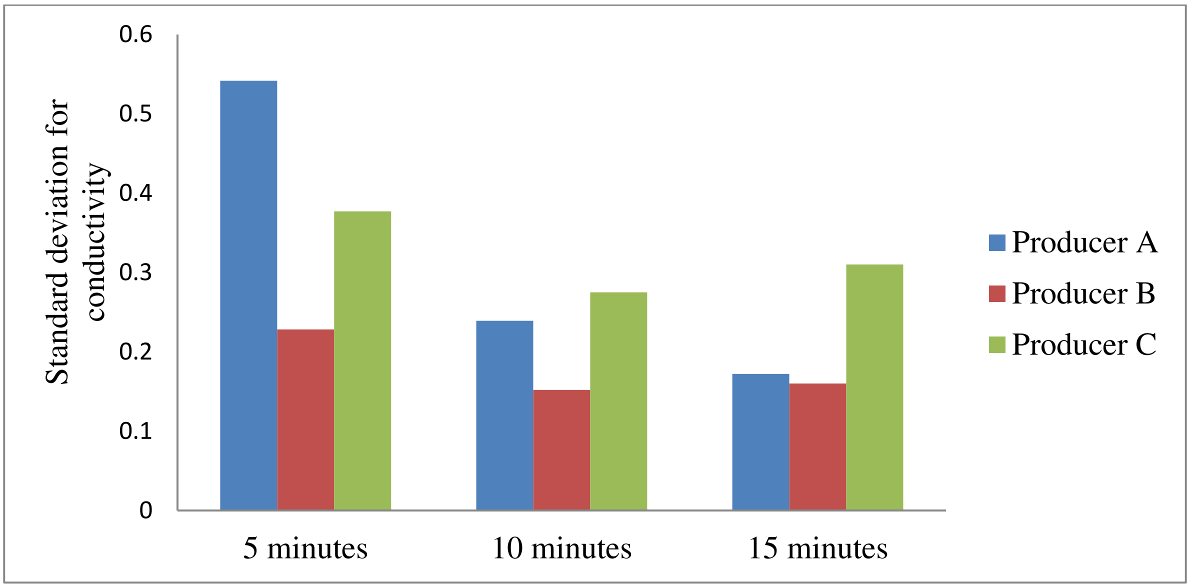

Figure 2: Variation of standard deviation of conductivity of salt with time-day 2

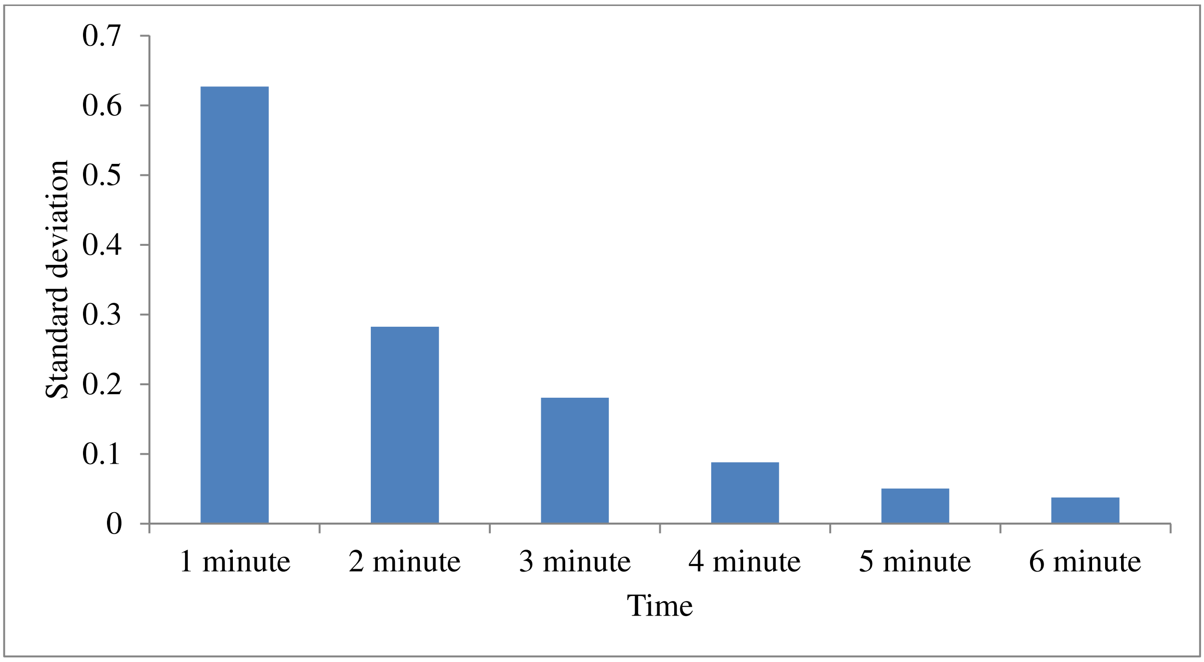

Figure 3: Variation of standard deviation of conductivity with mixing time using kenwood food processor

3.2 Effect of mixing ratio and mixing time as causes of variability in Ga *kenkey*

The ratio of *aflata* to raw dough used can affect the texture of Ga-*kenkey* produced. The more the *aflata* used the softer the *kenkey,* and vice versa. Mixing time also affects the texture of the Ga-*kenkey* produced. The more time allowed for mixing, the softer the Ga-*kenkey*.

3.2.1 Texture profile analysis

An instrument texture analysis was conducted on nine balls of Ga-*kenkey* products used in the sensory analysis. Results of the analysis are presented in Table 1. The parameters measured included hardness, cohesiveness, adhesiveness, springiness, gumminess, chewiness, and resilience.

3.2.1.1 Hardness

Hardness is the peak force of the first compression of a product (Bourne, 1982). It could be seen that for any particular mixing ratio, mixing time of 4 minutes recorded the lowest values for hardness while mixing time of 2 minutes recorded the highest values for hardness. This could be due to damage to the integrity of the granules as mixing time increases. According to Barrera, et al. (2012) starch damage changes the structure of the granule which in turn affects rheological behavior and functional properties of the starch systems. So, the more time allowed for mixing the softer the Ga-*kenkey* becomes.

As the raw dough portion of mixing ratio is increased for any particular mixing time, the properties of the Ga-*kenkey* also changed. This could be due to increases in undamaged starch granules. Damage enhances swelling of granules due to destruction of the forces which prevent granules from swelling in water. Hence, damaged starch has the ability to absorb more water than native granules (Barrera et al.,2012).The less damaged starch available the less water will be absorb during cooking and harder the Ga-*kenkey* becomes.

From Table 2 below, there is significant interaction ($P>0.05$). This means that mixing ratio used and mixing time both contribute to the variability in Ga-*kenkey* quality. Much of the variability (97.84%) in hardness could be explained by mixing ratio and mixing time use.

3.2.1.2 Cohesiveness

Cohesiveness is defined as the degree to which a substance is compressed between the teeth before it breaks (Civille and Szczesniak, 1973). It is measured as the area of work during the second compression divided by the area of work during the first compression (Bourne, 1982).

From Table 2 below, at a significance level of 0.05 neither mixing ratio nor mixing time significantly affected cohesiveness. Interaction of mixing ratio and mixing time is also not significantly different. R square (adjusted) is 0.00%.This means that the variability in cohesiveness cannot be explained by the mixing ratio and mixing time used, and could be due to other factors.

3.2.1.3 Adhesiveness

Adhesiveness is defined as the force required in removing materials that adheres to the mouth (generally palate) during the normal eating process in relation to sensory (Civille and Szczesniak, 1963).

Mixing time did not significantly influence the adhesiveness of the *kenkey* ($P>0.05$). The interaction effects of mixing time and mixing ratio significantly ($p<0.05$) the adhesiveness. Much of the variability (R2adj = 80.23%) in adhesiveness could be explained by the mixing ratio used and how long it was mixed. This is summarized in Table 2 below.

3.2.1.4 Springiness

Springiness is defined by Civille and Szczeniak (1973), as the degree to which a product returns to its original shape once it has been compressed during the first compression. Springiness is measured by the distance of the detected height of the product on the second compression divided by the original compression distance (Bourne, 1982).

The interaction of mixing ratio and mixing time did not significantly affect springiness. However, there is a significant difference ($P<0.05$) in the type of mixing ratio used. The type of mixing ratio used contributed to 44.63% (R2adjusted) of variability in springiness of various *kenkey* samples. This is summarized in Table 2 below.

3.2.1.5 Gumminess

Gumminess is defined according to Civille and Szczesniak (1973) as denseness that persists throughout mastication; energy required to disintegrate a semi-solid food to a state ready for swallowing. Gumminess applies only to semi-solid products and is calculated as hardness × cohesiveness.

There is significant interaction ($P<0.05$) between the type of mixing ratio used and mixing time. And this interaction contributed to 91.36% (R2adjusted) of variability in gumminess of Ga-*kenkey* samples. This is summarized in Table 2 below.

3.2.1.6 Chewiness

According to Civille and Szczesniak (1973), chewiness is defined as the length of time (in sec) required to masticate a sample at a constant rate of force application, to reduce it to a consistency suitable for swallowing. Chewiness applies only to solid products and is calculated as Gumminess × Springiness (Bourne, 2002).

Table 2 below summarized the result. There is significant interaction ($P<0.05$) between the type of mixing ratio used and mixing time. And this interaction contributed to 99.02% (R2adjusted) of variability in chewiness of Ga-*kenkey* samples.

3.2.1.7 Resilience

Resilience is defined as a measure of how the sample recovers from deformation (Stable Micro System, 1996). It is measured on the withdrawal of the first penetration, before the waiting period is started. It is calculated as the area during the withdrawal of the first compression divided by the area of the first compression.

There was significant interactions ($P<0.05$) between the type of mixing ratio used and mixing time. And this interaction contributed to 82.00% (R2adjusted) of variability in gumminess of *kenkey* samples. This is summarized in Table 2 below.

Table 1: Texture profile analysis of Ga-*kenkey*

Code	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
374	3.37±1.56	-121.2±2.1	0.47±0.09	0.37±0.18	0.12±0.07	0.10±0.09	0.21±0.05
102	3.23±0.35	-8.28±0.18	0.52±0.11	0.41±0.19	1.33±0.02	0.73±0.05	0.33±0.18
010	2.84±0.59	-11.87±1.2	0.61±0.05	0.46±0.14	1.29±0.05	0.79±0.05	0.39±0.18
198	72.89±21.5	-140.1±9.8	0.45±0.14	0.37±0.15	15.46±0.62	11.39±0.09	0.51±0.09
299	59.19±13.2	-35.48±7.5	0.44±0.08	0.47±0.26	23.74±9.46	11.68±3.64	0.40±0.04
357	15.79±4.87	-12.04±2.7	0.49±0.20	0.48±0.17	8.29±0.03	7.43±0.70	0.62±0.09
891	15.21±4.14	-36.67±6.5	0.33±0.16	0.56±0.29	14.23±2.49	2.43±0.46	0.65±0.02
069	10.39±0.63	-40.67±8.2	0.33±0.13	0.61±0.25	8.19±0.21	1.45±0.47	0.69±0.56
476	3.24±0.76	-47.68±2.4	0.39±0.08	0.49±0.20	1.19±0.07	0.39±0.49	0.58±0.09

374-1:1 mixed for 2 minutes 102-1:1 mixed for 3 minutes 010-1:1 mixed for 4 minutes
198-1:2 mixed for 2minutes 299-1:2 mixed for 3minutes 357-1:2 mixed for 4 minutes
891-2:3 mixed for 2minutes 069-2:3 mixed for 3minutes 476-2:3 mixed for 4minutes

Table 2: Source of variability of instrumental texture parameters

Texture attribute	Source of variability	P-value	R^2 and R^2 adjusted
Hardness	Mixing ratio Mixing time Interaction	0.000 0.000 0.000	R^2 = 98.86% R^2 adjusted = 97.84%
Cohesiveness	Mixing ratio Mixing time Interaction	0.380 0.503 0.565	R^2 = 42.91% R^2 adjusted = 0.00%
Adhesiveness	Mixing ratio Mixing time Interaction	0.000 0.344 0.006	R^2 = 89.53% R^2 adjusted = 80.23%
Springiness	Mixing ratio Mixing time Interaction	0.009 0.236 0.811	R^2 =70.71% R^2 adjusted = 44.68%
Gumminess	Mixing ratio Mixing time Interaction	0.000 0.002 0.000	R^2 = 95.43% R^2 adjusted = 91.36%
Chewiness	Mixing ratio Mixing time Interaction	0.000 0.000 0.000	R^2 = 99.48% R^2 adjusted = 99.02%
Resilience	Mixing ratio Mixing time Interaction	0.000 0.225 0.008	R^2 = 90.47% R^2 adjusted = 82.00%

3.3 Consumer acceptability of *kenkey*

Three mixing ratio (*aflata*: dough) were each mixed for three different times. The mixing ratios used were 1:1; 1:2; 2:3 and the mixing times of 2, 3, and 4 minutes were employed. The resulting products were moulded, and cooked into *kenkey*. The *kenkey* samples were evaluated for consumer acceptability using randomized incomplete block design in appendix .Fifteen sensory panelists who were familiar with the characteristics of *kenkey* in a 9-point hedonic scale (9 = dislike extremely, 5 = neither dislike nor like, and 1 = like extremely) preference test. The level of preference in terms of colour, smell, taste, smoothness, hardness and overall acceptability of *kenkey* produced are presented in Table 3.

All the *kenkey* samples were not significantly different from one another from one level of treatment to another at the 95.0% confidence level since the P-value is greater than 0.05.

Friedman's rank test (Table 3) showed that *kenkey* produced traditionally by using the mixing ratio 1:1 and mixed for 3 minutes in the kenwood mixer was most acceptable (having highest rank sum). It was followed in second place by *kenkey* produced by using the mixing ratio of 2:3 and mixed for 2 minutes *kenkey* produced by using mixing ratio 1:1 and mixed for 4 minutes was ranked the least. The rank test showed that even dough there was no significant difference between the samples, the type of mixing ratio and mixing time used affect the consumer acceptability of the final product. The sensory analysis confirmed the results of earlier studies done by Bediako-Amoa(1976) that among indigenous Ga people mixing ratio of 1 to 1 is preferred.

Table 3: Sensory attributes of Ga-*kenkey* produced using different mixing ratios and times

	Sensory attributes					
Sample	**Colour**	**Smell**	**Hardness**	**Smoothness**	**Taste**	**Overall acceptability**
1:1 2min	7.33±1.86	6.5±1.64	5.0±1.55	6.33±1.86	6.0±2.19	6.33±1.97
1:1 3min	7.83±1.17	7.33±1.21	7.33±1.21	7.5±1.38	7.5±0.55	7.33±1.21
1:1 4min	5.33±1.21	5.83±1.17	6.5±1.05	5.83±1.94	5.67±1.86	5.33±1.51
1:2 2min	7.5±0.55	6.83±1.17	75.33±1.37	6.17±1.47	6.33±1.21	6.67±1.75
1:2 3min	7.17±1.17	6.0±1.67	5.67±2.16	7.17±1.60	6.0±2.09	5.83±1.83
1:2 4min	7.0±1.79	7.5±1.05	5.17±2.48	7.5±1.05	6.5±1.38	6.33±1.75
2:3 2min	7.17±1.47	6.67±1.21	5.33±1.37	7.17±1.17	7.17±1.17	6.83±1.33
2:3 3min	7.67±1.03	7.33±1.51	4.5±1.38	6.67±1.37	5.83±2.32	6.67±1.86
2:3 4min	6.5±1.87	7.0±1.09	5.33±2.25	6.5±1.05	5.83±1.17	6.67±0.82

Table 4: Friedman's ranking scores for overall preferences of *kenkey* samples

Sample	Sum of Ranks	Order of Ranks
1:1 2min	38	4th
1:1 3min	44	1st
1:1 4min	32	6th
1:2 2min	40	3rd
1:2 3min	35	5th
1:2 4min	38	4th
2:3 2min	41	2nd
2:3 3min	40	3rd
2:3 4min	40	3rd

3.4 Relationship between sensory texture and instrumental texture profile analysis

Sensory texture was assessed by how many panelists. The only sensory parameter assessed by sensory panelists used was hardness, while instrumental texture measured parameters like hardness, adhesiveness, cohesiveness, springiness, gumminess, chewiness, and resilience. However, because the sensory panelists were not fully trained, it is necessary to correlate instrumental hardness with sensory hardness to find out whether the panelists were able to assess the hardness correctly. From the correlation matrix below (Table 5), there was negative correlation of instrumental hardness with sensory hardness. This is because the smaller the value of sensory hardness, the harder and less preferred the *kenkey* was, while the larger the value of instrumental hardness the harder and less preferred the *kenkey* was.

Table 5: Pearson's correlation of sensory and instrumental hardness

		Hardness (sensory)	Hardness(instrumental)
Hardness (sensory)	Pearson Correlation	1	-0.168
	Sig. (2-tailed)		0.505
Hardness (instrumental)	Pearson Correlation	-0.168	1
	Sig. (2-tailed)	0.505	

Conclusion

A major source of variability of Ga-*kenkey* arises from the variation in the time or extent of *aflata* mixing, even by the same producer. *Aflata* mixing ratio and mixing time have a significant impact on the hardness, adhesiveness, springiness, gumminess, chewiness and resilience of the Ga-*kenkey* produced, but not on the cohesiveness of the Ga-*kenkey*. Variation in the mixing ratio used, and mixing duration affect the physical characteristics, and consumer acceptability of the final product. The findings from this study could be used for industrial production of consistent quality Ga-*kenkey.*

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Appendix 1: Work sheet for sensory evaluation of the kenkey samples prepared from different treatments of mixing times and mixing ratios using balanced incomplete block design(t=10, b=15, N=60,k=4, λ=2). Using hedonic scale of 1-9 to score the following attribute.

	SAMPLES									
BLOCKS	1	2	3	4	5	6	7	8	9	10
1	010	102	476	789						
2	010	102			374	198				
3	010		476				069	357		
4	010			789					891	299
5	010				374		069		891	
6	010					198		357		299
7		102	476			198			891	
8		102		789			069			299
9		102			374			357		299
10		102					069	357	891	
11			476		374				891	299
12			476			198	069			299
13			476	789	374			357		
14				789	374	198	069			
15				789		198		357	891	