

Original Research Article**EFFECT OF BAKING TEMPERATURE ON THE QUALITY OF
BAKED SWEET POTATO CRISPS****ABSTRACT**

The study investigated the effect of baking temperature on the quality characteristics of baked sweet potato crisp samples. The developed products were baked using five baking temperature levels (110°C , 120°C , 130°C , 140°C and 150°C). The result of the proximate analysis shows that moisture content ranged between 3.31 to 5.76 %, crude protein 2.61 to 3.22 %, fat 8.93 to 14.01%, crude fibre 2.59 to 4.79 %, ash 2.56 to 3.59 % and carbohydrate 71.56 to 78.15%.

The result of the textural properties (with  baked crisp samples having the same width (33mm) and thickness (150mm) showed the force at peak of the baked crisp samples ranged between 5.83 to 20.30 N, deformation at peak ranged between 1.33 and 2.22mm, while deformation at break ranged between 1.88 and 3.69mm. The force at peak increased as the baking temperature increased. Sensory evaluation of the baked sweet potato crisps showed that crisp sample baked at 120°C had the highest sensory rating of all the samples in terms of overall acceptability.

Keywords: Sweet potato, baked crisps, proximate, textural, sensory.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* (L)) originated in the tropical America where it is grown extensively and is now one of the major root crops in the developing world, where over 90% of the production is found (Scott, 1991; Adam, 2005). The crop is now cultivated throughout the tropics and subtropics and ranked among the most important crops worldwide (Rufai and Omonona, 2012). It is considered to be a nutritionally rich crop; and as well rich in vitamins (B₁, B₂, C, E), minerals (calcium, magnesium, potassium and zinc), dietary fiber, and non-fibrous carbohydrates (Hagenimana *et al.*, 1993; Odebode *et al.*, 2008; Aina *et al.*, 2009; Picha and Padda, 2009).

According to FAO (2008) about 35 to 95% of the 3318000 MT annual production of sweet potato in Nigeria is being wasted and value addition offers good potential for income generation and employment as well as for enhanced utilization of the crops. This provides a means to reduce poverty, improve food security and nutrition which is in line with the current Millennium Development Goals (MDGs).

Value addition and processing of crops which generally entails transformation of raw outputs into other forms of products with higher value and diversified utilities helps in providing an array of products, reduces post harvest losses, enhances the taste of the products and eliminates anti-nutritional factors in crops (Odebode *et al.*, 2008; Oluwole *et al.*, 2012; Oluwole *et al.*, 2013). This with the present campaign of increasing food production, utilization and consumption of tradition food as a means of effectively combating the problem of food and nutrition insecurity makes the concept of product development as well as value addition necessary among other things (Wheatly *et al.*, 1995). However, proper value addition entails detailed research (Sanni *et*

44 *al.*, 2003), especially when developing a new product in order to optimize the production
45 parameters as well as come out with an acceptable product.

46 Snacks foods comprises a very large array of food items among which are crisps, chips, crackers,
47 nuts, extruded snacks among others (Harper, 1981); which may be produced through the
48 application of heat in an oven (baking); and snack and baked foods has been playing a very vital
49 role in the diet of the modern day consumers (Chung and Pomeranz, 1983; Tettweiler, 1991;
50 Wainwright, 1999); supplying their daily nutrient and calories intake (Amany *et al.*, 2012; Aliyu
51 and Sani, 2009).

52 Currently, there are increasing demands for low-fat or fat-free snack products (Moreira, 2001)
53 which make the demand for baked products to increase as against fried products. However the
54 properties of baked products are naturally influenced by process parameters such as baking
55 temperature, thus carrying out research on the effect of baking temperature is necessary to obtain
56 a final product with desirable characteristics. Therefore, this study aims at investigating the
57 effect of different baking temperatures on the utilization of sweet potato in the production of
58 baked snacks.

65 **2. MATERIALS AND METHOD**

66 **2.1 Materials:**

67 Yellow fleshed sweet potato was purchased from a local market in Lagos State, Nigeria. Other
68 materials used include vegetable fat, portable water, spices (ground pepper) and seasoning.

69

70 **2.2 Method:**

71 **2.2.1 Production and product formulation of baked sweet potato crisps**

72 Table 1 shows the formulation used in the development of the baked sweet potato crisps

73

74 Table 1: Formulation/recipes for the production of baked sweet potato snacks

S/N	Ingredient	Weight (gms)	% by weight
1	Sweet potato dough	882	95.25
2	Binder	18	1.94
3	Vegetable fat	20	2.16
4	Seasoning (Curry powder, Maggi cube)	3.2	0.35
5	White pepper (dry)	1.8	0.19
6	Salt	1	0.11
Total		926	100

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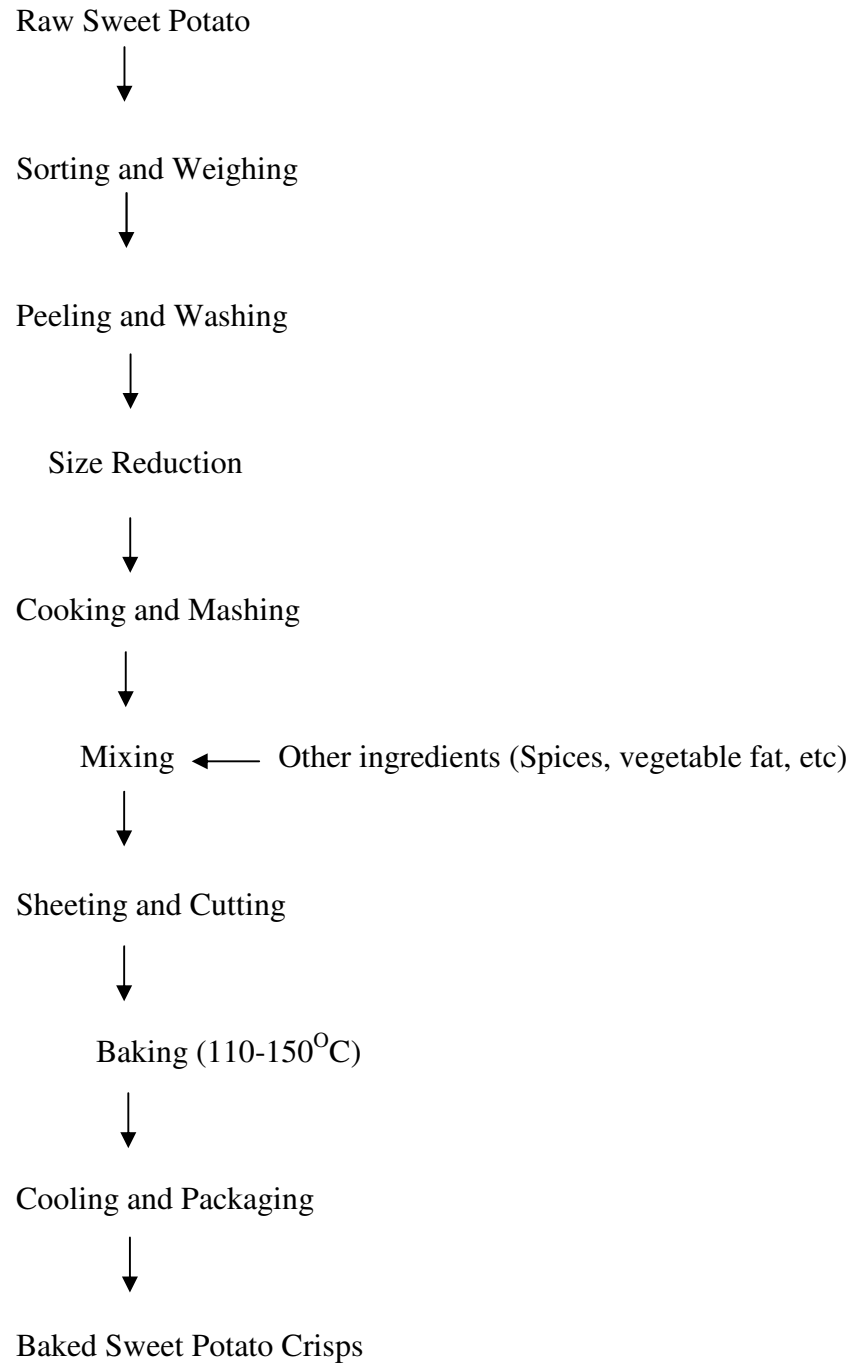


Fig 1: Production of baked sweet potato crisps

2.2.2 Crisps Snacks Preparation

The production flow chart is as shown in Fig 1. Upon careful and weighing, the raw sweet potato were peeled and washed after which they were cut into smaller size and cooked with water for about 30 – 35 mins till well cooked sweet potato is obtained which is subsequently mashed. Thereafter, the mashed sweet potato along with other ingredients transferred into a mixer (Hobart) and the content mixed thoroughly for about 30mins to obtain dough of desired texture.

The mixed dough was manually sheeted on a stainless steel tray of a height 150mm giving the sheet the thickness of 150mm of using a rolling pin and cut into circular shape using a 33mm diameter biscuit cutter. Aluminium foil was used to prevent dough sticking to the rolling pin. The cut dough pieces were later transferred to a baking tray lined with aluminium foil (Olapade *et al.*, 2011). The snacks were baked in a pre-heated air circulation oven (Memmert, Typ: UM 400) at prescribed different temperatures for a period of 40 ± 5 mins and allowed to cool for 30 mins at room temperatures. Each batch of the baked snacks samples were properly packed in high density polyethylene bag prior to analysis.

2.2.3 Baking Temperature

The sample was baked at five different temperatures of 110°C, 120°C, 130°C, 140°C and 150°C for a period of 40 ± 5 mins each

Where Sample A = Baking temperature of 110°C.

B = Baking temperature of 120°C.

C = Baking temperature of 130°C.

D = Baking temperature of 140°C.

E = Baking temperature of 150°C.

2.3 ANALYSES

2.3.1 Proximate Analysis

The quantitative evaluation of moisture content, crude fibre, crude protein, fat and ash of the sample were determined using the method of AOAC (2005). Carbohydrate was obtained by difference:

$$\text{Carbohydrate} = (100 - (\text{moisture} + \text{crude protein} + \text{crude fibre} + \text{fat} + \text{ash})) \%$$

2.3.2 Textural Analysis

The baked samples were subjected to textural analysis using Testometric Universal Testing Machine (Serial No. 500 – 689; Capacity – 25KN). They were fractured to complete failure in the three-point bending as described by Vincent (1998). Specifically, parameters such as force at peak, energy at peak, deformation at peak and deformation at break were determined.

2.3.4 Sensory Evaluation

The baked sweet potato crisp samples were organoleptically evaluated for different sensory quality attributes and overall acceptability as described by Ihekoronye and Ngoddy (1985), using a 9-point hedonic rating method where 1 represents “extremely unacceptable” and 9 represent “extremely acceptable”. The mean of sensory scores for attributes - colour, taste, after-taste, flavour, crispiness, mouth-feel and overall acceptability of the developed products were recorded and analyzed.

2.3.5 Statistical Analysis

The results of the proximate, textural and sensory analysis were compared using one-way analysis of variance (ANOVA) and the significant differences between baked mean values of the baked sweet potato crisps samples carried out using Duncan's multiple range test (DMRT). Also, Pearson's correlation matrix between the proximate and textural parameters was done using SPSS version 17.

172 3. RESULTS AND ~~DISCUSSION~~

173 3.1 Proximate Composition

174 Table 2: Proximate composition of baked sweet potato crisp samples

Proximate	Baked sweet potato crisp samples				
Composition (%)	A	B	C	D	E
Moisture	5.67 ^a	5.41 ^{ab}	5.06 ^{bc}	4.63 ^c	3.31 ^d
	± 0.26	± 0.17	± 0.14	± 0.09	± 0.11
Crude protein	2.88 ^{ab}	2.99 ^a	2.90 ^{ab}	2.61 ^b	3.22 ^a
	± 0.08	± 0.12	± 0.06	± 0.13	± 0.09
Fat	10.00 ^d	10.72 ^c	14.01 ^a	13.46 ^b	8.93 ^e
	± 0.14	± 0.09	± 0.15	± 0.17	± 0.10
Crude fibre	2.59 ^c	4.79 ^a	2.88 ^c	2.90 ^c	3.83 ^b
	± 0.14	± 0.08	± 0.11	± 0.05	± 0.12
Ash	2.87 ^b	2.42 ^b	3.59 ^a	2.59 ^b	2.56 ^b
	± 0.16	± 0.13	± 0.15	± 0.07	± 0.13
Carbohydrate	75.90 ^b	73.67 ^c	71.56 ^d	73.81 ^c	78.15 ^a
	± 0.12	± 0.13	± 0.07	± 0.14	0.15

175 Values are mean of three determinations ± is SD values

176 Mean values having different superscript in the same row are significantly different (p<0.05)

177

178 Table 2 shows the proximate composition (%) of baked sweet potato crisp samples. Moisture

179 content ranged between 3.31 to 5.76%, ash 2.42 to 3.59%, crude fibre 2.59 to 4.79%, crude

180 protein 2.61 to 3.22%, fat 8.93 to 14.01% and carbohydrate 70.86 to 78.15%. It revealed a

significant difference ($p < 0.05$) of baking temperature on the proximate compositions of the samples. The reason for this may be attributed to the reduction in the moisture content of the samples as the baking temperature increases (Yoon *et al.*, 1999); and this reduction might have subsequently caused the concentration of some of the other proximate parameters.

3.2 Textural Properties

Table 3: Textural properties of developed baked sweet potato crisp samples

Baked sweet	Textural Properties		
potato crisp	Force @ Peak (N)	Deformation @ peak	Deformation @ break
samples		(mm)	(mm)
A	$5.83^c \pm 0.60$	$2.22^a \pm 0.40$	$2.24^{bc} \pm 0.24$
B	$6.45^d \pm 0.30$	$2.08^a \pm 0.16$	$2.59^b \pm 0.57$
C	$11.77^c \pm 0.54$	$1.33^b \pm 0.06$	$1.88^c \pm 0.04$
D	$18.63^b \pm 0.16$	$2.09^a \pm 0.18$	$2.43^{bc} \pm 0.12$
E	$20.30^a \pm 0.10$	$1.59^b \pm 0.12$	$3.69^a \pm 0.08$

Values are mean of three determinations $\pm$ represents SD values

Mean values having different superscript in the same column are significantly different ($p < 0.05$)

The result of the textural properties of the developed baked sweet potato crisps samples showed significant difference ($p < 0.05$) in the effect of baking temperature on the some of the textural

properties determined. Generally, textural properties are mostly related to physical (especially mechanical) characteristics of foods products; and most dry crispy/crunchy food products have porous structure consisting of beams and films of solid materials surrounding air cells; thus variation in the water activity of the product would have effect on the force-deformation characteristics, as well as the number of sound peaks due to softening or otherwise of the air cell (Luyten *et al.*, 2004; Arimi *et al.*, 2010).

The force at peak value was used to represent the hardness of the baked sweet potato crisp samples (Bourne, 1982; Mochizuki, 2001); and products with higher force at peak may be considered to have higher hardness (Sawant *et al.*, 2013); the higher the value of force at peak the higher the hardness of the sample to fracture. The result shows that as the baking temperature increases, the force at peak increases. This can be directly attributed to loss of moisture with increase in temperature.

The maximum value for deformation at peak was recorded for sample baked at 110⁰C while sample baked at 130⁰C recorded the minimum value. Generally, the deformation at peak value of the samples first decreases with increase in baking temperature till 130⁰C before increasing and then decreasing.

The deformation at break value of the samples revealed that sample baked at 150⁰C recorded the maximum value with sample baked at 130⁰C recording the minimum value. There was an increase in the value after which it decreases at a baking temperature of 130⁰C before increasing again.

3.3 Sensory Attributes

Table 4: Sensory attributes of baked sweet potato crisps samples

Sensory	Baked sweet potato crisp samples				
Attribute	A	B	C	D	E
Colour	7.75 ^a ± 0.26	7.42 ^{ab} ± 0.14	7.16 ^{bc} ± 0.12	7.16 ^{bc} ± 0.20	7.00 ^{bc} ± 0.43
Taste	7.33 ^a ± 0.11	7.42 ^a ± 0.14	7.25 ^{ab} ± 0.10	7.08 ^{bc} ± 0.16	7.00 ^c ± 0.10
Flavour	7.00 ^a ± 0.08	6.80 ^a ± 0.20	6.80 ^a ± 0.20	7.20 ^a ± 0.40	6.30 ^b ± 0.30
Crispiness	6.90 ^c ± 0.20	7.60 ^a ± 0.40	7.00 ^{bc} ± 0.12	7.42 ^{ab} ± 0.24	6.83 ^c ± 0.06
Mouthfeel	7.08 ^a ± 0.10	7.25 ^a ± 0.20	7.00 ^a ± 0.06	7.33 ^a ± 0.20	6.75 ^b ± 0.22

Mean values having different superscript in the same row are significantly different (p<0.05)

± represents SD values



Color has an important sensory attribute known to strongly influence the acceptability of a food product (Surkan *et al.*, 2009; Krokida *et al.*, 2001) because oftentimes, it is the only attribute that consumers can base their purchasing decisions on (Meilgaard *et al.*, 1991). The result of the colour from the sensory analysis of the baked sweet potato crisps revealed that most of the panelists preferred samples baked using the lower baking temperatures of 110⁰C and 120⁰C as samples baked with this two temperatures received higher sensory ratings. The preference of the panelists for the colour of these samples may be due to the fact that the colour of the samples produce from these two temperatures is lighter when compared with that of higher temperature. The increase darkness of the colour of product with increase in baking temperature can be

234 directly linked to the effect of non-enzymatic browning reactions such as Maillard reaction
 235 (Massini *et al.*, 1990) which is a reaction of a reducing sugars (glucose and fructose) and an
 236 amino group of protein at elevated temperature. This trend was also observed by Shyu and
 237 Hwang, (2001) in their work on chips.

238 In terms of taste, sample baked at 120⁰C received the highest rating but does not differs
 239 significantly ($p>0.05$) from samples baked at 110⁰C and 130⁰C. Sample baked at 150⁰C recorded
 240 the least score though  not significantly differs  ($p>0.05$) from sample baked at 140⁰C.
 241 ~~Though~~ sample baked at 140⁰C recorded the highest score in terms of  ~~but~~, it does not differs
 242 significantly ($p>0.05$) from samples baked with 110⁰C, 120⁰C and 130⁰C while sample baked at
 243 150⁰C recorded the least score.

244 Crispiness represents the key textural attributes of dry snacks products; denoting freshness and
 245 high quality, generally a crisp should be firm and snaps easily when bent, emitting a crunchy
 246 sound (Vickers and Bourne, 1976; Dueik *et al.*, 2010). Its loss can be caused by increased
 247 moistness of the product which can be a major cause of consumer rejection. If the moisture of
 248 products increases due to water sorption from the atmosphere or by mass transportation from
 249 neighbouring components, it results in a soggy and soft texture (Nicholls *et al.*, 1995). The
 250 panelists rated samples baked at 120⁰C highest followed by sample baked at 140⁰C however it
 251 does not show any significant different ($p>0.05$) with sample baked at 120⁰ while sample baked
 252 at 150⁰C was scored the least. The reason for this might as a result of over dryness of the product
 253 at the baking temperature of 150⁰C which makes it very hard. This same reason was put forward
 254 by Vickers and Bourne, (1976), noting that crisp products, while relatively firm, should not be
 255 overly hard and should snap easily.

Based on the mouthfeel, sample baked at 140°C was rated highest by the panelists; however, it did not differ significantly ($p>0.05$) with sample baked at 120°C. Similarly, sample baked at 150°C recorded the least sensory rating.

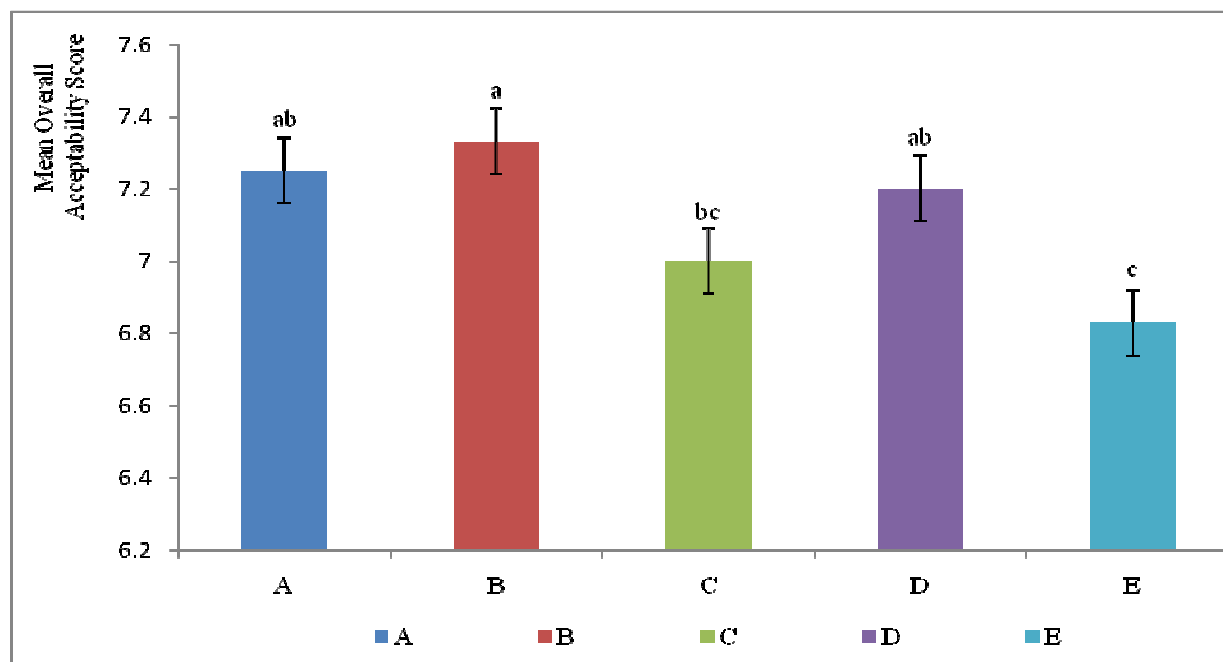


Figure 2: Mean overall acceptability of baked sweet potato crisps samples

With respect to the overall acceptability of the baked sweet potato crisp samples (fig 2), the most preferred sample by the panelists was sample baked at 120°C followed by sample baked with 110°C, 140°C and 130°C and lastly 150°C. Though, there was no significant difference ($p>0.05$) in the overall acceptability rating between sample baked at 120°C and samples baked at 110°C and 140°C, there was a significant difference ($p<0.05$) between this sample and samples baked at 130°C and 150°C, while samples baked at 110°C and 140°C also showed a significant difference ($p<0.05$) between sample baked at 150°C. According to the rating/assessment of Sharma *et al.*,

(1996) who put 7 as the cut-off score for perceptible change on a 9 point sensory scale, it can be concluded that sample baked at 150⁰C do  met the overall acceptability sensory criteria.

3.4 Correlation Matrix

Table 5: Pearson's correlation matrix between proximate parameters and textural properties of baked sweet potato crisp samples

	M C	CP	Fat	CF	Ash	C	F@P	D@B	D@P
Moisture Content (MC)	1								
Crude Protein (CP)	-.479	1							
Fat	.290	-.680*	1						
Crude Fibre (CF)	-.173	.520	-.410	1					
Ash	.242	-.142	.555	-.571	1				
Carbohydrate (C)	-.564	.513	-.880**	.127	-.527	1			
Force @ peak (F@P)	-.873**	.023	.086	-.103	-.130	.327	1		
Deformation @ break (D@B)	.484	-.516	-.190	-.025	-.443	.164	-.304	1	
Deformation @ peak (D@P)	-.799**	.700*	-.677*	.473	-.621	.751*	.501	-.225	1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

The correlation matrix (table 5) revealed a strong negative correlation ($p < 0.01$) between moisture content and textural properties of both force and deformation at peak. The negative correlation between moisture content and force was also corroborated by Tabibloghmany *et al.*, (2013) in

their work on potato chips. Fat also showing a negative correlation ($p < 0.05$) deformation at peak; conversely, both crude protein and carbohydrate showed a positive correlation ($p < 0.05$) with deformation at peak.

4. CONCLUSION

The study has revealed the possibility of producing crunchy baked sweet potato crisps using a baking temperature range not exceeding 140°C ; this is because temperature is an important factor in baking as it controls non-enzymic browning (Millard reaction) and choosing within this range will give product with desirable qualities. There is however need to strike a balance between the desirable sensory qualities and the textural properties to ensure product that would be acceptable to consumers.

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