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Rheological Study and Quality Characteristics of Yoghurt Produced From Blend of Tiger Nut and Whole Milk with Date Fruit as Sugar Substitute

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Abstract

The formulation of composite yoghurt at varying proportion from blends of whole milk and tiger nut with date fruit as sugar subtitute, focusing on health, nutrition and economic capability becomes imperative in a dynamic and challenging food system. This necessitated the need to study the rheological properties along with the quality properties and consumer's acceptability of yogurt. Yoghurt samples were produced from whole milk and tiger nut milk in varying ratio of Whole milk-tiger nut (100:0, 90:10, 80:20, 70:30, 60:40 and 50:50) and Tiger nut-whole milk in reverse order, respectively. About 20g of date fruit powder was added to each formulation to replace sugar. Rheological properties, Qualities charateristics and mineral composition of these samples were evaluated along side the consumer acceptability.The rheological studies revealed that all the yoghurt blends displayed a non-Newtonian behaviour. The power law model well fitted the shear stress-shear rate relationship of all the yoghurt blends with coefficient of determination (R^2) ranging between 0.99999-1. The consistency coefficient (k) and the uniformity index (n) ranged from 39.26-95.75 N/m^2s and 0.9984-1.003, respectively. Significant difference ($p<0.05$) existed in the proximate composition and the mineral composition with range of value of 109.41-975.00 mg/100g (calcium), 35.01-760.26 mg/100g (magnesium), 53.42-81.42 mg/100g (potassium), 0.35-0.61 mg/10mg/100g (zinc) and 327.83-822.34 mg/100g (phosphorus) respectively. The senesory parameters values were significantly favourable interms of preferrence and acceptance towards 50:50. This study showed that incorporation of tiger nut milk and date fruits in whole powdered milk for yoghurt commercial production suggested favorable nutritional impact on the consumers.

Keywords: Yoghurt, Quality characteristics, Tiger nut milk, Whole milk, Date fruit, Sugar substitute

1.0 Introduction

Yoghurt is a semi-solid fermented milk product, a well-known food reported to contain probiotics (Patel *et al.,* 2017; Moore *et al.,* 2018). The yoghurt production with addition of fruits and vegetables have been attempted by some researchers (Raut *et al.,* 2015; Deepa *et al.,* 2016; Govindammal *et* al., 2017). Yoghurt from a blend of milk (a dairy source) and plant (tiger nut) with a natural sugar replacer (date fruit) proposes an economical and nutritious product for domestic and industrial application (Deepa *et al.,* 2016; Govindammal *et al.,*2017). Tiger nut (*Cyperus esculentus* L.) is a root tuber that is a member of the family *Cyperaceae* (Bamishaiye *et al.*, 2011) and one of the underused tubers in West Africa, which has useful amino acids, fatty acids, soluble fibers, vitamins, minerals and phytochemicals (Sanful, 2009). *Phoenix dactylifera* (date fruit) belongs to a family *Arecacean* and an edible sweet desert fruit; it was reported that its fruit contain numerous medicinal properties, phytochemical constituents and important vitamins (Abdel-Magied *et al.,* 2018).

In a bid to win consumer appeal along health promotion, nutrition and economic capability, composite yoghurt innovatively formulated and produced from blends of milk, tiger nut and date fruit powder need to be attempted. The cholesterol and increasing number of lactose intolerance in children and adults who favourably consume yoghurt produced from cow milk are important factors considered in this suggested formulation. Reports in the literature revealed that excess sugar in the body may lead to weight gain, blood sugar problems and an increased risk of heart disease (Xiao *et al.,* 2022: Bolaji *et al.,* 2024a). Understanding the rheological properties of food is necessary in characterizing and predicting the behavior in food system and in the design of food plant and equipment (Krokida *et al.,* 2001). Therefore, the objectives of this study was to evaluate rheological properties and quality characteristics of yoghurt produced from whole milk and tiger nut blends at varying proportions with a fixed weight of date powder as a sugar substitute.

2.0 Materials and Methods

A 2kg Cowbell brand of powder milk, 3kg each of dates and tiger nut were purchased from Sabo market, Ikorodu, Lagos State, Nigeria. The milk from tiger nut was produced as shown in Figure 2.1. and as reported by Charles *et al.* (2015). Batches of fresh tiger nut samples were cleaned and soaked in cold water for 24 h at ambient temperature and milled with the aid of Usha mixer grinder -500W. A muslin cloth 0.02 micrometer was used to remove the chaff from the tiger nut milk (Figure 2.1). The date seeds were removed and weighed into an already heated laboratory oven at a temperature of 65 ^{o}C for 4 h. The dried date fruits were milled into powder and sieved and stored in a plastic container prior to subsequent process and analysis.

The preparation of date flour is as shown in Figure 2.1. This followed the method reported by Platat *et al.* (2015) with little modification. The date fruit cleaned with water to remove dirt. Seeds were removed and the pericarp was oven dried at 75^{0}C for 8h, milled and sieved through a 0.35 µm mesh sieve. The date fruit powder was packaged for further processing.

Preparation of the blends of whole milk- tiger nut powdered-date fruit yoghurt is as shown in the Figure 2.1, Column 3. Tiger nut milk and whole milk were prepared as shown in Table 2.1 in the ratio of cowbell and tiger nut milk: MT_{100} (100:0), MT_{90} (90:10), MT_{80} (80:20), MT_{70} (70:30), MT_{60} (60:40), MT_{50} (50:50), while for Tiger nut milk: whole Milk were also in similar order but reversed (TM_{40}(60:40),TM_{30} (70:30), TM_{20} (80:20), TM_{10} (90:10), T_{100} (100:0).

2.1 Production of Yogurt from Whole milk-Tigernut Milk

Each blend was prepared into sterilized jars for pasteurization at 72 ^{o}C for 15 mins. The jars were allowed to cool to 45^{o}C and then inoculated with a mixed culture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Deepaj *et al.*, 2016; Patel et al., 2017; Govindammal *et al.*, 2017). The inoculated samples were fermented in an incubator set at 42 ^{o}C for 10 hrs and cooled to 5-6 ^{o}C, stirred and kept under refrigerated condition of 4 ^{o}C for further analysis. About 20g of date powder was added to each formulation instead of sugar.

Table 2.1: Formulation of tigernut-date fruit yoghurt

Sample	Whole Milk (%)	Tiger nut (%)	Date Powder (g)
MT_{100}	100	0	20
MT_{90}	90	10	20
MT_{80}	80	20	20
MT_{70}	70	30	20
MT_{60}	60	40	20
MT_{50}	50	50	20
TM_{40}	40	60	20
TM_{30}	30	70	20
TM_{20}	20	80	20
TM_{10}	10	90	20
T_{100}	100	0	20

2.2 Viscosity Measurement

The viscosity of different yoghurt samples with control were measured in 400 ml beaker in triplicates at varying spindle speed of 12, 30 and 60 rpm and varying time of 5, 10, 15, 20, 25 and 30s, respectively using a digital rotational viscometer (NDJ-86) as reported by Bolaji *et al.* (2024[b]). The samples were poured into the beaker to a level of immersion groove on the spindle shaft. The respective shear stress was computed with Microsoft Excel 2010 from the viscosities and plotted against the shear rate using the power law model in Equation 2.1 and 2.2.

$$\sigma = k\,\gamma^{n} \quad \text{.......... Equation 2.1}$$

$$\log \sigma = \log K + n \log\gamma \quad \text{.......... Equation 2.2}$$

Where:

k, is the consistency coefficient with the units: N/m^2s is the shear stress at a shear rate of (s^{-1}) and the exponent *n*, is the dimensionless flow behavior index . This indicates closeness to or deviation from Newtonian flow.

. Tiger Nut ↓ Cleaning ↓ Soaking (in cold water for 24h) ↓ Wet milling ↓ Filtration (using muslin cloth) ↓ Tiger nut milk	Date fruits ↓ Weighing ↓ Deseeding ↓ Sorting ↓ Washing ↓ Drying (oven 65°C for 3hrs) ↓ Milling ↓ Sieving ↓ Date powder	Mixed milk powder and tiger nut milk ↓ Pasteurization (72 °C) ↓ Cooling (45°C). ↓ Addition of starter culture Incubation (10 h at 42°C) ↓ Addition of date flour (20g) ↓ Mixing-yoghurt ↓ Packaging ↓ Refrigeration (at 5°C)

Figure 2.1: Production of tiger nut milk, date fruit and MT-yoghurt

2.3 Determination of Proximate Composition, and Brix Value of Yoghurt Samples

Moisture, ash, carbohydrate, protein, fat, and crude fibre were determined using standard methods (AOAC, 2015). The Brix values of samples were measured in trpilicate by refractometer (Zubairi *et al.*, 2021).

2.4 Sensory Evaluation

Sensory evaluation was carried out on the yogurt samples using a nine point – hedonic scale where 1 represented extremely disliked and 9 liked extremely (Bolaji *et al.* 2024[b]). A panel consisting of 20 judges were selected based on familiarity with the yoghurt products and on indication of interest.

2.5 Statistical Analysis

Results were expressed as mean values and standard deviation of three (3) replicates. Data were analysed using a one-way analyses of variance (ANOVA) using Statistical Package for Social Science (SPSS) version 20.0 software 2011 to test the level of significance at 5% probability ($p<0.05$) level.

3.0 Results and Discussion

3.1 Rheology Properties of the Yoghurt

The results of rheological properties of the yoghurt are as shown in Table 3.1. The consistency coefficient (k), uniformity index (n) and associated coefficient of determination (R^2) using the power law equation are also presented in Table 3.1. The viscosity of all the yoghurt samples decreased with increase in the spindle speed. A similar behavior was recorded for shear stress and consistency.

These values obtained in Table 3.1, may have been affected by the heterogeneous nature common to food materials (Krokida *et al.*, 2001; McKenna and Lyng, 2003). The consistency coefficient (k) ranged from 25.96-95.74 mpas^n. The coefficient of determination (R^2) obtained were high, indicating that power law was adequately suitable for describing the flow behavior of the yoghurt samples irrespective of the tiger nut inclusion. The consistency coefficient (k) serves as a viscosity guide of a fluid system and higher values indicate a more viscous fluid and will determine the pumpability of the fluid (Krokida *et al.*, 2001; McKenna and Lyng, 2003; Ome *et al.* 2018;). The results in this study showed pseudoplastic fluids at varying stages and probably tending towards a Newtonian fluid considering the uniformity index (n). This was in line with the result of Ome *et al.* (2018) who reported same for blends of whole milk and soybean powder; however, it was contrary to the report of Sopade and Kassum (1992). According to Arora *et al*. (2016), the fiber oncentration may influence the consistency coefficient (k). The researchers established the relationship between consistensy and sensory viscosity rating (SVR)

Table 3.1: Rheological properties of yoghurt produced from whole milk, tiger nut and date fruit

Sample	**Spindle Speed**	**K (mpas^n)**	**N**	**R^2**
M_{100}	12	95.745	1.0039	1
	30	41.166	0.9901	1
	60	43.681	1.0098	1
MT_{90}	12	92.94	1.0052	0.9998
	30	41.08	0.998	1
	60	40.528	1.0024	0.9999
MT_{80}	12	86.002	0.9956	1
	30	39.366	1.0012	1
	60	39.13	1.0019	1
MT_{70}	12	89.073	0.9899	1
	30	41.098	1.0075	1
	60	40.611	1.0075	1
MT_{60}	12	92.206	0.9949	1
	30	45.956	0.9787	0.9974
	60	44.079	1.0128	1
MT_{50}	12	86.339	0.9984	1
	30	39.258	0.9953	1
	60	40.315	1.0034	1
T_{100}	12	84.089	1.004	1
	30	36.359	1.014	0.9998
	60	36.359	1.014	0.9998
TM_{10}	12	77.272	0.993	1
	30	37.274	-1.002	0.9998
	60	32.696	0.994	0.9999
TM_{20}	12	78.315	0.997	1
	30	36.86	1.003	1
	60	33.453	0.998	0.9999
TM_{30}	12	79.168	-0.988	0.9989
	30	37.15	-0.997	0.9986
	60	32.073	0.987	0.997
TM_{40}	12	85.70	1	1
	30	38.121	-0.993	0.9986
	60	34.454	0.989	0.9977

Key:M_{100} (100% whole milk; 0 % tiger nut), MT_{90} (90 % whole milk; 10 % tiger nut), MT_{80} (80 % whole milk; 20 % tiger nut), MT_{70} (70 % whole milk; 30 % tiger nut), MT_{60} (60 % whole milk; 40 % tiger nut), MT_{50} (50 % whole milk; 50 % tiger nut), TM_{40}(60% tiger nut milk and 40% whole milk),TM_{30} (70% tiger nut milk and 30% whole milk), TM_{20}(80% tiger nut milk and 20% whole milk), TM_{10} (90% tiger nut milk and 10% whole milk), T_{100} (100% tiger nut milk,0% whole milk).

3.2 Proximate Composition and Brix Value

The proximate composition of the composite yoghurt is as presented in Table 3.2. Significant differences ($p<0.05$) existed between values reported for the samples. The moisture content ranged from 79.00-80.97%. The inclusion of tiger nut up 10, 20 and 30% showed an increase in the carbohydrate content; this was contrary to the observation for protein content which increased with increased tiger nut addition. The ash content recorded for the yogurt samples were higher in the icnreased tiger nut inclusion. These however were connected to the consitutent of the yogurt. High moisture contents of food samples indicated an increased water activity and may affect the keeping quality (Igbabul *et al.*, 2014). The ash contents varied from 0.67-1.07%. This was lower compared with values reported by Kavas and Kavas, (2016) and Kemelo *et al.*, (2019). The values reported for protein in this study were higher compared with values reported by Kemelo *et al*. (2019) and Charles *et al*., (2015).

The fat contents which may be a useful indicator of flavour and have a tendency to influence processing, packaging and storage of the composite yoghurt products were within the range of values reported by Chinedu *et al.* (2012) however they were lower compared with values reported by Kavas and Kavas (2016) for frozen yoghurt. Kemelo *et al*. (2016) reported classification of yoghurt based on fat content: 3.25% of fat content (yoghurt), 0.5-2.0% (low-fat yoghurt) and less than 0.5% (non-fat yoghurt). The protein and fat content were significantly influenced by the addition of tiger nut. This similarly affected the fat content and brix values of the samples which decreased with increase in the tiger nut. Higher value protein content was recorded in this work compared with values reported by some researchers (Raut *et al.,* 2015; Govindammal *et al*., 2017). The values obtianed in this work categorised all the blends of yoghurt to low-fat yoghurt. The brix content reduced with increase in tiger nut inclusion and wthin the values reported by Othman *et al.* (2019).

3.3 Mineral Content of Yoghurt Produced from Whole Milk, Tiger Nut and Date Fruit

The mineral composition of the yoghurt is as shown in Table 3.3. The results obtained for mineral content of the composite yoghurt were significantly higher compared with reports from previous work this may be connected with addition of tiger nut milk and date fruits (Sanful, 2009; Gahruie *et al.* 2019).

The result revealed that calcium, magnesium and phosphorus contents reduced with the increase in the addition of tiger nut. This was contrary to the observation noted for zinc and potassium. The value of calcium and phosphorus in this study were lower when compared to the values reported by Gahruie *et al.* (2019). The values of zinc in this study were lower when compared to the values reported by Gad *et al.* (2010). The values of magnesium content were higher than those reported by Amellal-Chibane and Benamara (2011).

3.4 Sensory Characteristics of Yoghurt Produced from Whole Milk, Tiger nut and Date Fruit

The results of sensory evaluation are as shown in Table 3.4. The values for taste, appearance, flavour, colour and overall acceptability ranged from 5.40-6.91, 5.85-6.78, 5.95-6.75, 5.15-6.45 and 5.65-7.88, respectively. With the exception of the overall acceptability, which was averagely scored 7.88 for MT_{100} (100% whole milk; 0% tiger nut; 20g date fruit) compared with values reported for MT_{50} (7.80) and TM6 (7.40), respectively, the senesory parameter values were significantly favourable in terms of preference and acceptability towards MT_{50} (50 % whole milk; 50 % tiger nut; 20g date fruit) and TM_{40} (60 % tiger nut milk and 40% whole milk with 20g of date).

Table 3.2: Proximate composition of yoghurt produced from whole milk, tiger nut and date fruit

Sample	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fibre (%)	CHO (%)	BRIX
MT_{100}	82.33±6.25^{b}	0.93±0.12^{cd}	2.00±0.00^{f}	4.83±0.03^{d}	0.09±0.00^{c}	9.81±6.11^{c}	16.23±0.21^{h}
MT_{90}	79.00±0.50^{a}	0.80±0.20^{c}	2.33±0.58^{fg}	2.31±0.02^{2}	0.05±0.00^{a}	15.51±0.71^{a}	14.30±0.26^{g}
MT_{80}	79.50±1.35^{a}	1.07±0.23^{d}	2.33±0.56^{fg}	3.21±0.02^{bc}	0.07±0.00^{c}	13.83±1.81^{e}	12.20±0.10^{f}
MT_{70}	80.10±0.66^{a}	0.80±0.00^{c}	2.33±0.55^{fg}	3.04±0.02^{b}	0.06±0.00^{c}	13.66±0.80^{e}	12.07±0.12^{f}
MT_{60}	80.17±1.04^{a}	0.67±0.12^{ab}	0.97±0.06^{e}	2.88±0.03^{b}	0.06±0.00^{d}	15.26±1.13^{f}	14.17±0.15^{g}
MT_{50}	81.48±0.25^{ab}	0.71±0.12^{b}	1.15±0.00^{f}	2.76±0.03^{b}	0.45±0.00^{d}	12.59±0.34^{d}	11.35±0.16^{c}
TM_{40}	84.67±1.77^{cd}	0.50±0.00^{a}	0.80±0.01^{d}	3.41±0.09^{c}	0.08±0.01^{c}	8.44±1.69^{b}	9.07±0.12^{d}
TM_{30}	86.17±3.75^{de}	0.83±0.29^{c}	0.73±0.01^{c}	4.64±0.09^{d}	0.07±0.00^{b}	7.12±3.40^{ab}	8.17±0.15^{c}
TM_{20}	86.67±2.08^{d}	1.17±0.28^{de}	0.54±0.01^{b}	5.08±0.09^{e}	0.06±0.00^{b}	6.92±2.06^{a}	8.10±0.17^{c}
TM_{10}	86.33±1.61^{d}	1.00±0.00^{d}	0.51±0.01^{ab}	5.52±0.09^{e}	0.05±0.00^{a}	8.69±1.51^{b}	7.57±0.12^{b}
T_{100}	87.67±1.53^{e}	1.17±0.29^{de}	0.43±0.01^{a}	6.50±0.09^{f}	0.04±0.00^{a}	6.86±1.81^{a}	7.00±0.00^{a}

*Mean ± standard deviation with same superscripts along the column are not significantly different at ($p>0.05$)

Table 3.3: Mineral content of yoghurt produced from whole milk, tiger nut and date fruit

sample	Calcium (mg/100g)	Magnesium (mg/100g)	Potassium (mg/100g)	Zinc (mg/100g)	Phosphorus (mg/100g)
MT_{100}	550.11^{d}	650.01^{d}	0.01^{k}	0.01^{a}	703.09^{e}
MT_{90}	975.00^{a}	760.26^{a}	0.06^{g}	0.01^{a}	822.34^{a}
MT_{80}	865.22^{b}	745.62^{a}	0.05^{h}	0.01^{a}	806.51^{b}
MT_{70}	850.15^{b}	725.01^{b}	0.04^{i}	0.02^{b}	784.21^{c}
MT_{60}	650.32^{c}	710.36^{bc}	0.02^{j}	0.01^{a}	768.38^{d}
MT_{50}	447.20^{e}	345.00^{e}	25.04^{f}	0.245^{c}	514.69^{gh}
TM_{40}	111.11^{j}	68.62^{i}	63.41^{e}	0.45^{e}	421.72^{b}
TM_{30}	114.10^{i}	70.95^{h}	65.82^{d}	0.35^{d}	425.16^{j}
TM_{20}	126.54^{h}	76.11^{g}	69.11^{c}	0.45^{e}	486.92^{i}
TM_{10}	134.23^{g}	82.34^{f}	71.52^{b}	0.52^{f}	524.35^{g}
T_{100}	151.14^{f}	82.45^{f}	81.42^{a}	0.61^{g}	571.14^{f}

*Mean ± standard deviation with same superscripts along the column are not significantly different at ($p>0.05$)

The values obtained in this study were similar to the values reported by Aderinola and Olanrewaju (2014) for yoghurt with inclusion of African yam bean. The taste and aroma of these samples may have been significantly impacted by the volatile compound initiated during incubation (Bolaji *et al.*, 2020). The results of the study showed that substitution of whole milk with tiger nut milk can increase the nutritional values as well as provide an economical subtitute to yoghurt solely from whole milk.

4.0 Conclusion

This study showed that it is possible to prepare yoghurt with varying percentage of tiger nut milk with date fruit as a sugar substitute.The financial impact of making yoghurt from dairy milk compared with when strategically combined with tiger nut milk and sweetened with a natural sugar substitute--date fruit may yield positive results. A cost-effective and wholesome product for use in both household and industrial settings is proposed by this combination. The rheological results showed a non newtonian fluid ($0<n<1$). The rheological behavior suggested a possible dependence on the heterogeneous nature of the yoghurt samples. The coefficient of determination (R^2) obtained were high, indicating that power law was adequately suitable for describing the flow behavior of the yoghurt samples produced from blend of whole milk and tiger nut. Tigernut supplementation has a major impact on the proximate and mineral composition. Strong preference and acceptance were shown for MM5

(50% whole milk, 50% tiger nut, and 20g date fruit) and TM64 (60% whole milk, 40% tiger nut milk, and 20g date).

Table 3.4: Sensory characteristics of yoghurt produced from whole milk, tiger nut and date fruit

Sample	Taste	Appearance	Flavour	Colour	Overall Acceptability
MT_{100}	6.91 ± 1.68^{c}	6.78 ± 1.54^{c}	6.75 ± 1.21^{a}	6.55 ± 1.82^{b}	7.88 ± 1.45^{a}
MT_{90}	5.45 ± 1.27^{e}	5.85 ± 1.04^{de}	6.08 ± 1.63^{b}	5.15 ± 1.73^{f}	5.65 ± 1.26^{fg}
MT_{80}	5.40 ± 1.09^{e}	6.05 ± 1.67^{d}	5.95 ± 1.43^{b}	5.75 ± 1.16^{d}	5.90 ± 1.37^{ef}
MT_{70}	6.60 ± 1.43^{c}	6.00 ± 1.14^{d}	6.40 ± 1.09^{ab}	6.45 ± 1.39^{bc}	5.86 ± 1.63^{b}
MT_{60}	6.70 ± 1.66^{c}	6.55 ± 1.61^{c}	6.60 ± 1.47^{ab}	6.20 ± 1.67^{c}	6.65 ± 1.23^{d}
MT_{50}	7.85 ± 1.38^{a}	7.75 ± 1.23^{a}	7.08 ± 1.42^{ab}	6.45 ± 1.32^{bc}	7.80 ± 1.49^{ab}
TM_{40}	7.60 ± 0.70^{b}	7.60 ± 1.61^{a}	7.20 ± 1.03^{c}	7.00 ± 1.01^{a}	7.40 ± 1.27^{c}
TM_{30}	6.60 ± 1.07^{c}	7.30 ± 1.25^{b}	6.60 ± 0.84^{bc}	7.00 ± 0.68^{a}	$6.90\pm.00^{cd}$
TM_{20}	6.00 ± 1.33^{d}	6.00 ± 1.56^{d}	5.70 ± 1.06^{ab}	5.90 ± 0.88^{d}	5.80 ± 0.42^{ab}
TM_{10}	6.00 ± 1.49^{d}	5.20 ± 1.93^{e}	5.60 ± 1.17^{ab}	6.30 ± 2.06^{c}	6.20 ± 1.13^{e}
T_{100}	6.00 ± 2.36^{d}	5.30 ± 1.16^{e}	4.80 ± 1.69^{a}	5.40 ± 0.90^{e}	5.60 ± 2.59^{fg}

*Mean ± standard deviation with same superscripts along the column are not significantly different at ($p>0.05$)

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