Abstract
Elephant foot yam (EFY), a nutritious tuber consumed as vegetable in India and other tropical countries is well recognized in Ayurveda for its healthful attributes. Being a good source of starch and, therefore, a potential thickening agent, pre-cooked powdered EFY was incorporated into milk and examined for its thickening potential as a function of yam solids (EFYS) and milk solids (TMS). Apparent viscosity and other physical properties viz., sedimentation, heat coagulation time (HCT-130°C), whiteness index (WI) along with sensory attributes of the resulting EFY-milk dispersion were studied using response surface methodology. Increasing solids level (9.17-14.82% TMS and 0.19-2.31% EFYS) resulted in linearly increasing (p<0.01) apparent viscosity (5.9-12.9 mPa.s), yam solids having more pronounced effect than milk solids, although the interaction between the two factors was non-significant. The increase in solids level was accompanied by decrease (p<0.01) in HCT (50.5-3.1 min) and WI (84.03-78.41), the effect of EFYS being accentuated at higher levels of TMS. Correspondingly, the sensory consistency score (42.7-19.4 on 100-point linear scale) declined with both increasing TMS and EFYS, whereas the color (96.0-72.7), mouthfeel (96.3-80.0) and flavor scores (90.6-66.6) all decreased, but essentially with increasing yam solids and not perceivably with milk solids. It was found that for given (tolerable) heat stability and sensory attributes of yam-milk mix, the levels of two components could be optimized to achieve desired thickening in various milk-food applications.

Keywords: Elephant foot yam, response surface methodology, apparent viscosity, sedimentation, heat stability, sensory attributes

Introduction
Non-communicable diseases (NCD's) like cardiovascular disease, cancer, chronic respiratory disease, diabetes and mental health conditions are posing a serious threat to the health and well-being of populations across the globe. These diseases are responsible for 63% of all deaths worldwide and are estimated to cost more than US$ 30 trillion over the next two decades, representing 48% of global GDP in 2010 (Bloom et al. 2011). These lifestyle related disorders have enhanced the demand for with enhanced functionality. Functional foods offer a practical and new approach to achieve optimal health status by promoting the state of well-being and reducing the risk of disease. The European Commission's Concerted Action on Functional Food Science in Europe defined 'functional foods' as food which improves health and well-being of humans and/ or causes disease risk reduction by beneficially affecting the bodily functions. These foods, instead of a pill, capsule or dietary supplement, are consumed as part of normal diet (FUFOSE, 2000). The functional foods segment of the food industry enjoys worldwide consumer support and is therefore growing at a brisk rate.

Elephant foot yam (Amorphophallus paeoniifolius (Dennst.) Nicolson) (or, Amorphophallus campanulatus Decne) (EFY), is a nutritious but underutilized tuberous vegetable. This high potential tuber crop is native to Asia (Lim, 2015). Because of its higher yield potential, culinary properties, medicinal utility and therapeutic values, it is referred to as King of Tuber Crops (Sengupta et al. 2008). It contains a wide range of phytochemicals i.e. alkaloids, phenols, flavonoids, glycosides, saponins, steroids and tannins (Ramalingam et al. 2010). Therapeutic uses of EFY include arsa (haemorrhoids), piliha (splenic disorders), gulma (tumor conditions), svasa (breathing disorders), kasa (cough) and asthila (prostate disorder).
(Ayurveda Pharmacopeia of India, 2007). It is beneficial in liver diseases, abdominal pain, emesis, dysentery, elephantiasis, diseases due to vitiated blood, rheumatic swellings (Ansil et al. 2012) and cough, heart disease and liver pain (Morvin Yabesh et al. 2014). Various extracts and metabolites obtained from the tuber have been well demonstrated to be possessing antimicrobial (Khan et al. 2008; Natraj et al. 2009), analgesic (Shilpi et al. 2005; Dey et al. 2010) and hepatoprotective effect (Ansil et al. 2012; Hurkadale et al. 2012). The tuber extracts have been found to possess anti-helminthic (Ramalingam et al. 2010), immune-modulatory (Tripathi et al. 2010), cytotoxic (Angayarkanni et al. 2007) and anti-inflammatory (De et al. 2010) activity. Recent work have showed that tuber extracts possess cytotoxic and apoptic activity against human colon carcinoma cell line HCT-15 (Ansil et al. 2014).

Dairy products are among one of the most preferred options to be formulated into functional foods by incorporation of non-dairy bio actives. Milk is preferred delivery vehicle for physiologically active ingredients due to convenience, flavor and nutritional value. It provides a medium to generate an array of products that fit into the consumer demand for health-based 'hybrid' dairy foods which offer health, flavor and convenience. Along these lines, milk could very well be considered to serve as a vector through which beneficial effects of elephant foot yam can be incorporated into human diet. Further, the yam-milk dispersion can be processed into other appropriate dairy foods. However, milk poses an inherently challenging environment for incorporation of yam due to various interactions and required processing treatment. Being rich in starch, the yam could serve as a thickening agent, as well. The use of processed yam powder in milk could be expected to have a pronounced thickening effect on the characteristics of the milk system, while designing EFY fortified dairy foods. The present study was designed to assess the effects of elephant foot yam solids (EFYS) and total milk solids (TMS) levels on viscosity and certain other physical properties and sensory attributes of the yam-milk dispersion.

Materials and Methods

Raw materials

Fresh cow milk was collected from the cattle yard of the institute. The processed yam powder used in the study was obtained by drying pre-cooked (30 min in excess boiling water) elephant foot yam at 60°C in a tray dryer (Accolab, Ambala Cantt., India). Coarse grinding of the dried yam was carried out using Maxie Food Processor (Inalsa, Noida, India). The resulting powder was then milled to a fine particle size (around 290μ) in a colloid mill (1093 Cyclotec, Foss Tecator AB, Sweden) fitted with a 52 mesh sieve.

Preparation of elephant foot yam-milk mix

Fresh cow milk was warmed to 40°C and filtered using muslin cloth to remove foreign particles. It was then standardized to a fat-to-SNF ratio of 0.17 and thermized at 65°C (no hold) and cooled to room temperature. The processed yam powder was blended into the milk and the mixture transferred to a refrigerator (6-8°C) for 30 min. The EFY-milk dispersion was then heated in a water-bath at 80°C for 5 min. The dispersion was cooled to 60°C and then homogenized at 175±5 kg/cm² (H-102, Goma Engineering, Mumbai). The dispersion was then stored in a refrigerator (6-8°C) till analysis.

Experimental design

The central composite rotatable design (CCRD) of response surface methodology (RSM) was used for RSM experiment with two factors viz., EFYS and TMS, ranging from 0.5-2.0% and 10-14%, respectively. The ranges of these process variables were determined through preliminary experiments. A total of 13 different combinations were worked out using Design Expert version 8.0.1. The responses studied were apparent viscosity (AV), sediment, heat coagulation time (HCT), whiteness index (WI) and sensory attributes (color, consistency, flavor and mouthfeel). The coded and actual values of the process variables in the RSM experiment are given in Table 1. Both the process variables contain five different levels: -1.413, -1, 0, 1 and +1.413. The experiments were performed randomly. The relationship between coded and an un-coded variable is given by the following equation:

\[
y_0 = \frac{(y - y_c)}{A\Delta y_0}
\]

where \(y_0\) is real value of variable; \(y_c\) is coded values of independent variable; \(\Delta y\) is mid value and \(\Delta y_0\) is change.

Analytical methods

The apparent viscosity of the mix prepared was measured at 20°C using coaxial cylindrical rotational viscometer (Viscostar plus L, Fungilab, Spain) with spindle TL5 at 100 rpm (shear rate, 132s⁻¹). 8 ml of the sample tempered at 20°C for 1 h was transferred to the sample tube (outer cylinder) and measurement carried out as described by the manufacturer. The temperature of the sample was maintained by a recirculating-water jacket connected to a water-bath. For sediment determination, 10 ml of yam-milk mix was taken in a 15ml centrifuging tubes. The tubes were centrifuged at 1000 rpm (REMI Centrifuge, Bombay, India) for 5 min. The volume of the sediment was directly read and expressed in millilitres.

Heat coagulation time (HCT) of yam-milk mix was determined...
employing the method of Davies and White (1966). Milk sample (1.5 ml) was taken in a Pyrex tube (both ends open) of 10 cm length and 0.8 cm inner diameter. The two ends of the tube were closed with the silicone rubber corks. After shaking gently the tubes were clamped onto an aluminium carriage of 12 tubes capacity. The carriage was placed in a paraffin oil bath previously heated to 130°C was started. The tubes were illuminated from above by a lamp to facilitate observation of milk clotting. As soon as the milk clotted, time was noted in minutes. Whiteness index (WI) was calculated according to Bolin and Huxsoll (1991) under:

\[
WI = 100 - \sqrt{(100 - L^*)^2 + a^* + b^*}
\]

Where \(L^*, a^*, \) and \(b^*\) are Hunter \(L^*, a^*, \) and \(b^*\) values obtained by employing spectro-colorimeter, Color flex 45/0 (Hunter Lab, Reston, USA). Before the test, the instrument was calibrated with standard black and white tiles as specified by the instrument supplier.

Sensory Evaluation

The prepared elephant foot yam-milk mix was evaluated for sensory characteristics by a panel of judges selected from the Faculty of Dairy Technology Division, National Dairy Research Institute, Karnal, India on a semi-structured, linear scale (0-100) for individual attributes. The linear scale was divided into 4 equal parts between the two extremes viz. 'extremely dark' to 'absolutely white' for color, 'very thin' (skim milk like) to 'definitely thick' (honey like) for consistency, 'bland' to 'intense off-flavor' for flavor and 'extremely smooth' to 'extremely grainy' for mouthfeel. The panellists were not particularly trained for the present study, but they were dairy professionals having adequate knowledge regarding the sensory evaluation methods and the product attributes. Panel members were asked to judge for color, consistency, flavor and mouthfeel using the respective linear scales and to put a vertical mark along the scale to indicate the attribute's intensity.

Statistical analysis

The RSM data obtained were analyzed using the Design Expert software version 8.0.1 (Statease Inc., Minneapolis, Minnesota, USA). The responses were related with the process variables using a response surface quadratic model:

\[
Y = b_0 + b_1A + b_2B + b_{11}A^2 + b_{22}B^2 + b_{12}AB + \varepsilon
\]

where the coefficients of the polynomial are represented by \(b_0\) (constant term), \(b_1, b_2\) (linear terms), \(b_{11}, b_{22}\) (quadratic terms), \(b_{12}\) (interactive term) and \(\varepsilon\) (random error); \(A\) and \(B\) represent the process variables (factors) elephant foot yam

### Table 1  Coded and actual values of the process variables in the RSM experiment

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Axial point</th>
<th>Factorial point</th>
<th>Centre co-ordinate</th>
<th>Factorial point</th>
<th>Axial point</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: EFYS (%)</td>
<td>-1.413</td>
<td>-1</td>
<td>0</td>
<td>+1</td>
<td>+1.413</td>
</tr>
<tr>
<td>B: TMS (%)</td>
<td>0.19</td>
<td>0.50</td>
<td>1.25</td>
<td>2.00</td>
<td>2.31</td>
</tr>
</tbody>
</table>

### Table 2  Regression coefficients and ANOVA of fitted quadratic model for apparent viscosity (AV), sediment, heat coagulation time (HCT) and whiteness index (WI) of the yam-milk mix

<table>
<thead>
<tr>
<th>Partial Coefficients</th>
<th>AV</th>
<th>Sediment</th>
<th>HCT</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>9.46</td>
<td>0.68</td>
<td>30.34</td>
<td>80.86</td>
</tr>
<tr>
<td>A-EFYS</td>
<td>2.49**</td>
<td>-6.25E-003NS</td>
<td>-14.66**</td>
<td>-2.00**</td>
</tr>
<tr>
<td>B-TMS</td>
<td>0.61**</td>
<td>-0.84**</td>
<td>-9.47**</td>
<td>0.210NS</td>
</tr>
<tr>
<td>A²</td>
<td>-0.12NS</td>
<td>-0.084**</td>
<td>-1.44NS</td>
<td>0.265NS</td>
</tr>
<tr>
<td>B²</td>
<td>-0.017NS</td>
<td>3.75E-003NS</td>
<td>-0.70NS</td>
<td>-0.078NS</td>
</tr>
<tr>
<td>AB</td>
<td>-0.10NS</td>
<td>-0.063NS</td>
<td>-1.93NS</td>
<td>-0.34NS</td>
</tr>
<tr>
<td>R²</td>
<td>0.99</td>
<td>0.97</td>
<td>0.98</td>
<td>0.92</td>
</tr>
<tr>
<td>Model F value</td>
<td>109.49**</td>
<td>55.41**</td>
<td>73.13**</td>
<td>16.65**</td>
</tr>
<tr>
<td>Adequate Precision</td>
<td>33.39</td>
<td>24.32</td>
<td>27.34</td>
<td>13.16</td>
</tr>
<tr>
<td>Lack of Fit</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

** Highly significant (p< 0.01); * Significant (p < 0.05); NS- not significant
solids and total milk solids, respectively. The analysis of variance tables were generated and the effect and regression coefficients of linear, quadratic and interaction terms were determined. The coefficients depicting the inter-relation between the process variables and responses are presented in Table 2 and 3. The fitted polynomial models were expressed as surface plots for visualization.

Results and Discussion

Effect of EFYS and TMS on apparent viscosity of the EFY-milk dispersion

Viscosity i.e. the measure of the internal friction of a fluid, is an important rheological property of milk and dairy foods. It not only affects the consumer acceptance of the finished product but is also relevant to the rate of heat transfer as well as flow conditions during processing (Dimassi et al. 2005). It is critical in designing of process equipment and performance of unit operations such as chilling, mixing, homogenization, pumping, pasteurization, sterilization etc (Velez-Ruiz and Barbosa-Canovas, 1998). Further, thickening of milk by various additives is relevant to several process applications and product manufacture.

The apparent viscosity is defined as the viscosity of a non-Newtonian fluid measured at a particular, single shear rate. The term 'apparent' signifies the non-Newtonian behaviour of the elephant foot yam-milk system. The flow behaviour of milk, whether Newtonian or non-Newtonian, essentially depends upon composition, temperature, pre-treatment and measurement conditions (McCarthy, 2011). Since the yam-containing milk was found to behave like a non-Newtonian fluid, its AV (100 rpm, shear rate- 132 s⁻¹) was measured as an indicator of the thickening effect. It can be seen from Fig.1 (a) that both the increasing TMS and EFYS in the yam-milk mix resulted in an increased viscosity (p<0.01) but the effect of yam solids was much more pronounced. A low viscosity value of 5.9 mPa.s was registered for 0.19 % EFYS and 12.0% TMS whereas a high of 12.9 mPa.s was noted for the combination of 2.31% yam solids and 12.0% milk solids. The coefficient estimates of AV (Table 2) indicated that the viscosity increase was essentially linear in both the cases, and that the quadratic terms were non-significant as also the interaction between the two factors. The regression analysis presented shows that the coefficient of determination (R²) for the quadratic model was 0.99 and the "lack of fit", which assesses the fitness of the model obtained, was not significant, suggesting the sufficient adequacy of the model in accurately predicting the AV of yam-milk mix made with any combination of the process variables within the ranges studied i.e. 9.17-14.82 %TMS and 0.19-2.31% EFYS. Further, the statistical analysis indicated that the model fitted the observed data well, the model F value being 109.49 (p<0.01). Milk is known to exhibit an increased viscosity with increasing concentration, the increase being generally linear at lower concentrations and exponential at higher concentrations (Prentice 1992). The viscosity increase is attributed primarily to increased volume fraction of the casein micelles and decreased inter-micellar spaces leading to increased interactions between casein micelles (Bienvenue et al. 2003). The linear increase in viscosity observed in the present study may be attributed to a relatively lower milk solids concentration (9.2-14.8% TMS).

The more pronounced increase in viscosity upon yam powder incorporation might be attributed to the correspondingly increased imbibition of water resulting in a greater rise in the starch-volume fraction. The 'Peak Viscosity' observed in viscoamylography is indicative of the water-absorption capacity of starch undergoing gelatinization and consequently its thickening power in a system like starch-milk mix. Ramakumar (2011) observed an appreciable peak viscosity for the elephant foot yam dried at 60°C (1897 mPa.s) or even at 70°C (1372 mPa.s), which implied that a substantial contribution

Table 3  Regression coefficients and ANOVA of fitted quadratic model for sensory responses of yam-milk mix

<table>
<thead>
<tr>
<th>Partial Coefficient</th>
<th>Color</th>
<th>Consistency</th>
<th>Flavor</th>
<th>Mouthfeel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>83.30</td>
<td>35.52</td>
<td>75.53</td>
<td>92.30</td>
</tr>
<tr>
<td>A-EFYS</td>
<td>-7.44**</td>
<td>5.59**</td>
<td>-8.33**</td>
<td>-5.09**</td>
</tr>
<tr>
<td>B-TMS</td>
<td>-2.24*</td>
<td>4.44**</td>
<td>-2.44NS</td>
<td>-1.01NS</td>
</tr>
<tr>
<td>A²</td>
<td>1.28NS</td>
<td>-0.22NS</td>
<td>1.31NS</td>
<td>-1.86NS</td>
</tr>
<tr>
<td>B²</td>
<td>0.38NS</td>
<td>-0.32NS</td>
<td>2.59NS</td>
<td>0.012NS</td>
</tr>
<tr>
<td>AB</td>
<td>-1.63NS</td>
<td>-3.65*</td>
<td>0.17NS</td>
<td>-1.88NS</td>
</tr>
<tr>
<td>R²</td>
<td>0.923</td>
<td>0.93</td>
<td>0.812</td>
<td>0.76</td>
</tr>
<tr>
<td>Model F value</td>
<td>16.76**</td>
<td>17.54**</td>
<td>6.08*</td>
<td>4.39*</td>
</tr>
<tr>
<td>Adequate Precision</td>
<td>13.62</td>
<td>13.90</td>
<td>7.60</td>
<td>6.50</td>
</tr>
<tr>
<td>Lack of Fit</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

** Highly significant (p< 0.01); * Significant (p < 0.05); NS- not significant
to the thickening of milk by yam powder would come from water absorption by the yam starch during heating of the dispersion. As analysed, starch is the major component of elephant foot yam, supported by Chhatopadhyay and others (2010). The phenomenon of retrogradation (re-association of starch molecules) leads to increase in the viscosity. The retrogradation of starch upon cooling must also have presumably contributed to enhanced viscosity caused by yam powder in milk. Based on the RSM data, the AV of yam-milk mix could be predicted by the equation given below:

\[
AV (\text{mPa.s}) = -0.32557 + 4.63880 \times A + 0.49529 \times B - 0.066667 \times A \times B - 0.20889 \times A^2 - 4.37500 \times 10^{-3} \times B^2
\]

Effect of EFYS and TMS on sedimentation of the milk dispersion

Sedimentation, indicating the dispersion's instability, is a major problem encountered during storage of several liquid food preparations. The problem of sedimentation is often severe in protein-poly saccharides systems. The phase separation associated with colloidal instability is linked with entropy of the system and occurs when free energy of the mixture is minimized (Hemar et al. 2001).

The coefficient estimates for the sediment model show that yam solid concentration had significant (p<0.01) positive effect on the sediment value of yam-milk mix, whereas the effect of total milk solids concentration was non-significant. Thus, with the increasing yam solids level sedimentation increased, the rate of increase falling off at the higher values of yam solids within the range evaluated (Fig 1 (b)). An EFYS level of 0.19% coupled with 12.0% TMS resulted in a sediment value of as low as 0.15 ml whereas 2.0% yam solids and 10.0% milk solids exhibited a high sedimentation of 1.0 ml. The increased sedimentation could be associated with the higher density of yam particles as compared to the rest of the dispersion. The particle size may also have contributed to the phenomenon, as sedimentation is a direct function of particle diameter, as per the Stoke's law,

\[
\nu = \frac{d^2(\rho_s - \rho_b)g}{18\eta_0}
\]

where \(\nu\) is sedimentation velocity, \(d\) is particle diameter, \(\rho_s\) and \(\rho_b\) are particle and liquid densities, respectively, \(g\) is gravitational acceleration and \(\eta_0\) is viscosity of liquid. Repulsive forces are inadequate to prevent sedimentation when particle size is large (Glahn 1982). Further, the possible interaction of milk proteins with polyphenolic compounds in the yam might have caused the formation of aggregates contributing to the sedimentation. Sedimentation in UHT processed whey-banana beverage is ascribed to interaction of protein and banana phenolics (Koffi et al. 2005). At higher values of yam solids, the sedimentation may have been counteracted by the hydrocolloid effect of the powder, resulting in decreased rate of sedimentation. The hydrocolloids negatively affect sedimentation by interacting with milk protein and increasing the viscosity of suspended medium (Towler, 1984). The increased viscosity due to milk solids could be considered to have further led to the decreased rate of yam-cast increase in the viscosity of the dispersion as reflected in the lower values of viscosity at the highest levels of TMS and EFYS (Fig. 1(a)). The sediment value of yam-milk mix formulation could be predicted by the equation given below:

\[
\text{Sediment (ml)} = -0.50736 + 1.27400 \times A + 0.026458 \times B - 0.041667 \times A \times B - 0.14889 \times A^2 + 9.37500 \times 10^{-4} \times B^2
\]

The coefficient of determination of this quadratic equation (R^2 =0.97) suggested that the equation could explain 97% of variation in the sedimentation value of the mix.

Effect of EFYS and TMS on heat coagulation time of the yam-milk dispersion

Heat processing of milk based drinks/ beverages, is carried out to eliminate/minimize microbes, and thereby making them fit for human consumption and storage stable. Therefore the assessment of the heat stability of the milk colloid i.e. ability of the colloid to withstand high processing temperatures without visible coagulation or gelation, becomes an absolute necessity. The heat coagulation time (HCT) is defined as the time that elapses between placing a sample of milk in an oil bath and the onset of visible coagulation (Singh, 2004). The HCT (at 130°C) of the milk-yam dispersion decreased nearly linearly with increasing yam solids and total milk solids (p<0.01) (Table 2) and the effect of each factor was particularly pronounced at higher levels of the other factor (Fig. 1(c)). An HCT value of 50.5 min for 0.5% EFYS and 10.0% TMS declined to 3.1 min for the dispersion comprising 2.31% EFYS and 12.0% TMS. Decrease in HCT with increase in yam solids level could be attributed to the corresponding increase in the starch content leading to greater water absorption and therefore higher milk-protein volume fraction as well as higher concentration of salt in the yam-free liquid fraction, which probably had a destabilizing effect on milk. Addition of starch to milk has been reported to cause an appreciable decrease in the heat stability of milk (Muir et al. 1991; Tziboula and Muir, 1993). Similarly, Nayak and others (2004) observed a decrease in heat stability of skim milk and destabilization of skim milk concentrate upon addition of corn starch. Decreased heat stability upon concentration of milk solids has long been known (Muir and Sweetser 1978; however, the effect of milk solids concentration, especially at lower levels of yam solids, in the present study was less pronounced primarily on account of the comparatively lower TMS range studied. The heat
Fig. 1 Effect of milk solids level (TMS) on (a) apparent viscosity (AV), (b) sediment, (c) heat coagulation time (HCT) and (d) Hunter whiteness index (WI) of milk concentrate as a function of added elephant foot yam solids (EFYS).

Table 4 Matrix depicting Pearson’s correlation coefficient between various instrumental and sensory responses

<table>
<thead>
<tr>
<th>Sensory Score</th>
<th>AV</th>
<th>Sediment</th>
<th>HCT</th>
<th>WI</th>
<th>Colour</th>
<th>Consistency</th>
<th>Flavour</th>
<th>Mouthfeel</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV</td>
<td>1</td>
<td>0.924**</td>
<td>-0.919**</td>
<td>-0.910**</td>
<td>-0.941**</td>
<td>0.819**</td>
<td>-0.888**</td>
<td>-0.746**</td>
</tr>
<tr>
<td>Sediment</td>
<td>0.924**</td>
<td>1</td>
<td>-0.733**</td>
<td>-0.951**</td>
<td>-0.869**</td>
<td>0.729**</td>
<td>-0.784**</td>
<td>-0.677*</td>
</tr>
<tr>
<td>HCT</td>
<td>-0.919**</td>
<td>-0.733**</td>
<td>1</td>
<td>0.707**</td>
<td>0.879**</td>
<td>-0.840**</td>
<td>0.785**</td>
<td>0.748**</td>
</tr>
<tr>
<td>WI</td>
<td>-0.910**</td>
<td>-0.951**</td>
<td>0.707**</td>
<td>1</td>
<td>0.821**</td>
<td>-0.655*</td>
<td>0.779**</td>
<td>0.698**</td>
</tr>
<tr>
<td>Colour</td>
<td>-0.941**</td>
<td>-0.869**</td>
<td>0.879**</td>
<td>0.821**</td>
<td>1</td>
<td>-0.794**</td>
<td>0.812**</td>
<td>0.717**</td>
</tr>
<tr>
<td>Consistency</td>
<td>0.819**</td>
<td>0.729**</td>
<td>-0.840**</td>
<td>-0.655*</td>
<td>-0.794**</td>
<td>1</td>
<td>-0.674*</td>
<td>-0.649*</td>
</tr>
<tr>
<td>Flavour</td>
<td>-0.888**</td>
<td>-0.784**</td>
<td>0.785**</td>
<td>0.779**</td>
<td>0.812**</td>
<td>-0.674*</td>
<td>1</td>
<td>0.519</td>
</tr>
<tr>
<td>Mouthfeel</td>
<td>-0.746**</td>
<td>-0.677*</td>
<td>0.748**</td>
<td>0.698**</td>
<td>0.717**</td>
<td>-0.649*</td>
<td>0.519</td>
<td>1</td>
</tr>
</tbody>
</table>

*Significant at p < 0.05; ** Significant at p < 0.01 (2-tailed).
coagulation time of the milk-yam dispersion could be predicted by the following equation:

\[ HCT (\text{min}) = 63.17239 + 2.26493 \times A + 1.06496 \times B - 1.28500 \times A \times B - 2.55844 \times A^2 - 0.17478 \times B^2 \]

Effect of EFYS and TMS on whiteness index of the yam-milk mix

Whiteness is defined as a measure of how closely a surface matches the properties of a perfect reflecting diffuser. The perfect white has reflectance values of 100% across the visible spectrum with corresponding colorimetric values of \( L^* = 100, a^* = 0 \) and \( b^* = 0 \) i.e. \( WI = 100 \). Whiteness index indicates the extent of discoloration/fading of color during the processing condition. As evident from the regression coefficient (Table 2), the elephant foot yam solids had a negative effect on the WI; whiteness decreased almost linearly with the increasing yam solids level. TMS had little effect on whiteness of the yam-milk dispersion at lower levels of yam solids and had a moderating effect on the darkening caused by yam at higher levels of the latter (Fig. 1(d)). The WI of the processed yam powder used in the study was observed to be 68.22, much lower than ideal whiteness value of 100. The WI of the elephant foot yam milk dispersion could be predicted by following equation:

\[ WI = 89.88295 - 6.58523 \times A - 0.64521 \times B + 0.022833 \times A \times B + 0.47111 \times A^2 + 0.01938 \times B^2 \]

Fig.2 Response surface plots showing effects of elephant foot yam solids and total milk solids on sensory responses viz., (a) color score, (b) consistency score, (c) flavor score and (d) mouth-feel score of the yam-added milk concentrate

Sensory attributes of yam-milk mix as influenced by the levels of EFYS and TMS

Consumer acceptance influences the success of any food
product and sensory evaluation is particularly important to measuring consumer acceptability and preference. Sensory intensity ratings of color, consistency, flavor and mouthfeel of the EFY-milk dispersion monitored as responses to variations in yam solids and total milk solids are presented in Fig. 2. A definite correlation was noticed between the sensory responses i.e. color score, consistency score and mouthfeel score and their instrumental counterparts i.e. WI, sedimentation and AV, respectively, as depicted by Pearson’s correlation coefficient (Table 4). The color score of the decreased with increasing EFYS (p<0.01) or TMS (p<0.05), but the decrease was much smaller with the latter. Further, the color-score decline caused by increasing TMS was less prominent at lower levels of EFYS and similarly, that caused by EFYS was smaller at lower TMS levels. Consequently, the color score of the yam-milk blend was 93.7 for the combination of 0.19% EFYS and 12.00% TMS as against 72.7 for 2.00% yam solids and 14.00% milk solids. These results were more or less in accordance with the instrumentally observed color (WI) (vide Fig. 1d). The decreased color score could thus be ascribed to the brown discoloration brought about by the addition of yam to milk. The effects of yam solid and TMS level on the sensorily perceived consistency were somewhat similar to those observed for AV, increasing levels of both the factors causing almost linearly increasing consistency rating (p<0.01). However, the sensory consistency increased appreciably more with increasing TMS when the EFYS levels were lower unlike when the same were higher, and similarly, with increasing yam solids, the consistency (intensity) rating increased to a greater extent at lower levels of milk solids than at higher levels; the interaction between the two factors was found to be significant (p<0.05). The minimum consistency rating of 19.3 was noted for the yam-milk mix containing 0.5% EFYS and 10.0% TMS, whereas the maximum (42.7) was observed for 2.0% yam solids and 14.0% milk solids.

It is evident from Table 3 that the negative coefficient of the linear terms of the quadratic regression equation was significant (p<0.01) for yam solids which implied that an increasing concentration of yam solids linearly decreased the flavor score. While the TMS level in itself did not appear to have any significant impact on the flavor score of the yam-milk dispersion, the adverse effect of yam solids was slightly accentuated at higher milk solids levels, although the interaction effect was non-significant. Presumably such a small extent of flavor incompatibility between milk and yam may be overcome by using suitable flavoring. Although at lower levels, either EFYS or TMS did not appear to have any perceivable impact on the mouth-feel of the yam-milk blend (Fig. 2(d)), at higher levels of one factor, the other factor, particularly yam solids, exhibited a significantly decreased (p<0.01) mouth-feel score.

The aforementioned sensory attributes of yam-milk dispersion can be prefigured by following models:

- **Color score**  =  + 110.16015 - 2.61637 * A - 2.05198 * B - 1.08333 * A * B + 2.2777B * A2 + 0.095312 * B2
- **Consistency score**  =  -49.18278 + 37.64089 * A + 7.19831 * B - 2.43333 * A * B - 0.39556 * A2 - 0.08063 * B2
- **Flavor Score**  =  + 202.55272 - 18.33797 * A - 16.66589 * B + 0.11667 * A * B + 2.33244 * A2 + 0.64675 * B2
- **Mouthfeel score**  =  + 83.35896 + 16.49363 * A + 0.98313 * B - 1.25000 * A * B - 3.31111 * A2 + 3.12500E - 003 * B2

**Conclusions**

Milk as a carrier for elephant foot yam was examined with a focus on the thickening effect of cooked-yam powder and other related physical properties and sensory attributes and consequently with an aim to improve the functional benefits. Addition of yam powder (0.2-2.8%) to milk with different solids concentrations (9-15%) resulted in a substantially increased viscosity of the liquid blend, but the viscosity increase was accompanied by appreciably increased tendency to sedimentation, and decreased whiteness and heat stability. Appreciable impact of the yam solids on the sensory attributes of the blend was also observed. Again, the increased consistency rating was accompanied by decreased mouth-feel (smoothness), color and flavor scores. However, the data generated through the response surface methodology followed in this study could enable optimization of the level of yam solids for the desired thickening effect without having an excessively undesirable effects on the sensory acceptability of the product. Appropriate flavoring could potentially help enhance the palatability of the yam-milk mix, so that the thickening effect of the healthful yam might effectively be utilized in various milk-food applications.

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