EVALUATION OF TOFU REPLACEMENT LEVELS FOR EGG YOLK IN MAYONNAISE PRODUCTION

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ABSTRACT
The research was carried out to investigate the replacement index of tofu in place of egg yolk in mayonnaise production. Egg yolk was replaced with tofu at varying levels of 100, 75, 50, 25 and 0% and physical properties (emulsion stability, spoonability, oil staining, film formation, viscosity, elasticity, colour and syneresis) were evaluated using a complete randomised design while data obtained were subjected to General linear model Univariate procedure. Results showed that using egg yolk alone in mayonnaise production yield a less viscous product than when tofu is applied. Tofu was more viscous and spoonable than egg yolk. There appeared to be a higher emulsion stability and viscosity in samples that had a replacement index of 75% and 25% respectively. However, tofu showed a lower stability than egg yolk. In general, tofu showed great potential as an efficient replacer of egg yolk in mayonnaise production and the best level of replacement showed was 75%.

Key words: Tofu, Mayonnaise, emulsion stability, spoonability, oil staining.

Introduction:
Mayonnaise is an oil in water emulsion with egg yolk as its emulsifier. It is a dressing made from vegetable oil, raw egg yolks and seasoning and used on salads and in sandwiches. A typical formulation for commercially made mayonnaise can contain as much as 80% vegetable oil. Water makes up about 7-8% and egg yolks about 6%. The remaining ingredients include vinegar about 4%, salt about 1%, and sugar about 1%. (Silvestre et al., 1999). Mayonnaise is prepared using several methods. On the average mayonnaise contains around 700kcal energy per 100grams. This makes mayonnaise a calorically dense food (Huffingtonpost.com, 2014). Mayonnaise is mostly fat though most of the fat is unsaturated because the edible oils used come from plant sources. It has also been identified as a good source of vitamin E. This is because eggs and edible oils from plant sources which are the two main ingredients are both rich in this antioxidant vitamin. Because of the antioxidant profile of mayonnaise, eating it might help decrease the risk of cardiovascular diseases, according to a study conducted on post-menopausal women (Greenfield, 2013). Eating mayonnaise in moderation ensures that the fat-soluble nutrients in the diet are absorbed efficiently by the body. Although egg possesses excellent emulsifying ability, its high cholesterol content is a major concern to consumers. Also, egg is relatively expensive making mayonnaise costly and unaffordable to low income earners.

The development of salmonella in yolk-containing food products is another concern to mayonnaise consumers. For these and other reasons several studies have been carried out on partial or complete replacement of egg in mayonnaise. Aluko and McIctosh (2005) have studied canola proteins in native and hydrolyzed forms in mayonnaise, wheat protein functionality in mayonnaise was studied by Ghouse et al., (2008), Goankar et al., (2010) have done a research on milk proteins emulsifying performance in mayonnaise and used both native and hydrolyzed milk proteins to stabilize mayonnaise. In the present study, graded levels of tofu in replacing egg yolk will be compared. Tofu is a product of soy beans. Soy beans have been an integral part of the diet of people in the Far East for more than 5,000 years. In early years, soy protein products were mainly used to meet nutritional needs, but more recently they have been used primarily for their unique functionality. In general, soybeans contain 35-40% protein, 15-20% oil and from 20-25% carbohydrates depending on the variety (Messina, 1995). Soybean is rich in calcium and phosphorus. It also contains Oflavononegenstein which lowers triglycerides and generally improves circulation by increasing the flexibility of the arteries. Soybean products in their various forms are known to possess certain functional properties that make them useful in food systems and they are generally attributed to the proteins and lecithin. Among these are emulsifying properties, whipping ability, dough forming ability with wheat flour, fat absorption (promotion and prevention), water absorption (uptake and retention), textural properties and such other properties that make them useful as food ingredients (Plahar et al; 1997). Lecithin, a complex mixture of phosphatides and other lipid and non-lipid materials is an example of a natural emulsifying agent; and it is commonly found in soy beans. Functional properties of soy proteins such as emulsification, gel formation, etc. have been widely investigated by several researchers such as (Ahmad et al., 2010); (Arjun et al., 2011);
(Fukushima, 1991); (Poongodi and Boopathy, 2012); (Vasu et al., 2011). The purpose of this research was to substitute egg with tofu in mayonnaise in varying degrees, in order to study the physical properties of the emulsion.

Tofu is made from curdled milk obtained from the cooked seeds of soybeans. Tofu is a low-calorie source of protein and fat (Hackett, 2017). This is beneficial for people with a concern for their weight. Tofu is ideal for those suffering from diseases of the circulatory system. This property is attributed to its richness in unsaturated fats, its high content of vitamin E and its lecithin content (Botanical-online, 2017). Therefore, producing mayonnaise from tofu may reduce the risk of cardiovascular diseases and provide an alternative for people with such problems. Tofu mayonnaise also provides variety and an alternative for people with egg allergy.

Materials and Methods

The study was conducted in the Agriculture Physical Laboratory of Faculty of Agriculture, Usman Danfodiyo University Sokoto. The school is in the ancient city of Sokoto, Sokoto state. The state is located in the extreme north west of Nigeria, near to the confluence of River Sokoto and Rima. It is in the semi-arid ecological zone, surrounded by sandy savannah and isolated hills. The mean annual temperatures is 28.3 °C (82.9°F), the warmest months are February to April, where the day time temperature can exceed 45°C (113.0°F). The highest recorded temperature is 47.2°C (117.0°F) which is also the hottest temperature in Nigeria (Ojanuga, 2006; SERC, 2010). Five mayonnaise samples, (A, B, C, D and E), were produced with Tofu replacing egg yolk at 0, 25, 50, 75 and 100% v/v, respectively (Table1). The samples were compared for physical characteristics.

Firstly, fresh eggs were broken and the yolk separated, then silken Tofu was produced. These were mixed in the appropriate ratios, with 250ml egg yolk serving as a benchmark. Lastly, each sample was evaluated for physical properties in triplicates. Three cups of soybeans were soaked in water and left overnight. The soaked beans were then removed and ground with three cups water which was then poured into a pot and boiled on a gas heating medium for one hour under a maintained temperature from 25 to 90°C while constantly stirring it. The puree was removed from heat and allowed to cool and then strained through a cheese-cloth to get soymilk. 20 ml of vinegar was added to the soymilk and gently mixed together. The mixture was transferred into a heatproof bowl and placed in a deep pan containing a small amount of water. A dishcloth was used to line the lid of the pan and covered tightly. It was allowed to simmer on medium heat until the tofu was set.

The egg yolk and tofu were put in a blender, in the appropriate ratio show in table above totalling up to 250 ml benchmark, 10 ml of vinegar and 0.3g of salt were added to each sample and then homogenized. The vegetable oil was slowly incorporated spoon by spoon until the mayonnaise reached the proper consistency.

Table 1: General experimental layout

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Inclusion level of tofu</th>
<th>Replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Egg yolk</td>
<td>Tofu</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>D</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

The following physical properties were determined in the experiment on three replicates of each mayonnaise sample in the following ways:

**Emulsion Stability** was tested by exposing each sample to heat for ten minutes. They were placed in a pan filled with 1/8 litre of water which was placed on medium heat and allowed to boil. The time it took for each treatment to separate was recorded and the treatment that separated within the shortest time was labelled the least stable and vice versa.

**Viscosity** was tested by measuring the number of seconds it took for 10 ml of each mayonnaise sample to travel from the top to the base of a 16.5 cm incline. The sample that got to the bottom within the shortest time was labelled the least viscous and vice versa.

**Fat staining** was tested by smearing a small amount of each mayonnaise sample on a filter paper. The diameter of the translucent patch indicating the amount of oil not absorbed was measured with a ruler and recorded.

**Day to syneresis** was measured by recording the number of days it took for each treatment to separate into its water and oil constituents. It is also an indication of the stability of the emulsion.

**Spoonability** was determined by measuring the height of each mayonnaise treatment in a spoon using a pair of dividers and determining the actual height.
with a ruler.

**Elasticity** was determined subjectively. The elastic extent of each treatment was visually observed and samples were ranked by allocating scores to each sample on a scale of 0-10.

**Film formation** was determined on samples by careful visual observation. The time it took for each treatment to form a film on its surface was recorded. Colour was ranked on a scale of 1-4 based on increasing yellowness. 1 – off white, 2 – very pale yellow, 3 – pale yellow, 4 – yellow

Treatment means were compared for the physical properties using SPSS, 2007 General Linear Model Univariate procedure and significant means were separated using Duncan Multiple Range Test.

**Results and Discussion**

There were significant differences (P>0.5) in physical properties of mayonnaise across treatments, except for the 25% tofu (B) treatments which had the least value for all the parameters studied but tend to be similar in to other treatment interns of emulsion stability and film formation. The physical parameters of mayonnaise result as indicated by the standard error was less than 1 for all the treatment except in viscosity and film formation.

Table 2, shows that there was a progressive increase in the mean values of two parameters namely spoonability and oil staining except for treatment B which differed from the others, as stated above. Two treatments had mean values of 0 namely 25% (B) in spoonability and elasticity and 100% (E) in elasticity. There was a decrease in emulsion stability with increasing levels of tofu. There was an increase in spoonability and oil staining with increasing levels of tofu. There was a decrease in elasticity with increasing levels of tofu. There was an increase in viscosity with increasing levels of tofu. With increasing egg yolk levels, there was a corresponding increase in the rate of film formation. Only 100% tofu showed syneresis. The other mayonnaise samples only showed complete or partial spoilage up to the time the experiment was terminated but no syneresis was observed. Treatment E had the highest value for the most number of parameters studied while treatment B had the least value for the most number of parameters studied. With increasing egg yolk content, there was a progressive increase in yellowness of mayonnaise samples. See table 3, below:

<p>| Table 2: Functional properties of Mayonnaise with varying levels of Tofu |
|--------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|</p>
<table>
<thead>
<tr>
<th>Inclusion level of tofu (%)</th>
<th>Emulsion Stability (secs)</th>
<th>Spoonability (cm)</th>
<th>Oil Staining (cm)</th>
<th>Elasticity (secs)</th>
<th>Viscosity (secs)</th>
<th>Film Formation (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.73&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.16&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.33&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.40&lt;sup&gt;c&lt;/sup&gt;</td>
<td>32.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>25</td>
<td>6.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.10&lt;sup&gt;c&lt;/sup&gt;</td>
<td>14.33&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>50</td>
<td>4.89&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.25&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>1.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.70&lt;sup&gt;b&lt;/sup&gt;</td>
<td>25.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.38&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>75</td>
<td>4.92&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.33&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.20&lt;sup&gt;c&lt;/sup&gt;</td>
<td>39.34&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.67&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>100</td>
<td>4.79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.42&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>23.78&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.67&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SE</td>
<td>0.39</td>
<td>0.03</td>
<td>0.13</td>
<td>0.08</td>
<td>3.60</td>
<td>1.07</td>
</tr>
</tbody>
</table>

a,b,c and d, means bearing different superscripts along the same column differ (P<0.005), SE. Standard Error

**Emulsion Stability**: Treatment B was the least separated after heating. It was therefore the most stable. Egg yolk lecithin as an emulsifier is as effective, and more stable than soy lecithin (Ecovatec, 2015). Because soy lecithin is also an excellent emulsifier, the combination of egg yolk and soy lecithin may be responsible for B having the highest emulsion stability. The higher the emulsion stability of a mayonnaise, the better the quality of the mayonnaise. Treatments A, C and D were statistically the same. Lecithin from egg yolk or soybean increased the stability of emulsions made with protein and lowered the interfacial tension of protein films more effectively than pure egg (Yamamoto and Araki, 1997). Because egg yolk lecithin has an excellent emulsifying ability, 100% egg yolk also had high emulsion stability. Adding tofu and egg yolk in the ratio 50:50 gave the same level of stability as 100%. Therefore, in terms of stability, treatment C is a cheaper alternative to treatment A. Treatment D also showed the same level of stability as both A and C therefore, it is a cheaper alternative to both. Treatment E showed the least resistance to heating and it separated within the shortest time. This shows that tofu is not as stable as egg yolk and using it alone gives a mayonnaise with a lower stability. Apart from being statistically the same, A, C and D were also statistically the same as both B and E. However, treatments B and E were statistically different. Kobra et al, 2014 obtained a similar result using soymilk as an emulsifier in mayonnaise. They discovered that 100% soymilk showed the least stability value compared to the other levels and a layer of oil was clear after 10 days but there was no
marked oil separation in the case of the other samples.

**Spoonability**: Treatment E had the highest spoonability and it was followed by D. This is because they had the highest content of tofu. Tofu is rich in cellulose which accounts for approximately 50% of the dry weight in soybeans, with very few calories (Shuhong et al., 2013). Its primary structure is a long chain of glucose units attached together by b(1,4) linkages. It is the ability of these chains to hydrogen-bond together into fibres that gives cellulose its unique properties of mechanical strength and chemical stability. On the other hand, egg yolk contains about 0.7% carbohydrate, mainly oligosaccharides bound to proteins, composed of mannose and glucosamine, 0.3% is free carbohydrate in the form of glucose. The high amount of cellulose in tofu may be responsible for the high spoonability of treatments having high levels of tofu. Treatment C was statistically the same as D which means addition of egg yolk up to 50% doesn’t significantly affect the spoonability of mayonnaise. Treatment A was statistically the same as C. This means there was no significant difference between 100% and 50% egg yolk treatments therefore, treatment C is a cheaper alternative to A. Treatment C was also the same as both A and D. However, treatments A and D were not the same. Treatment B, for unexplainable reasons as already mentioned, was the least spoonable owing to its watery consistency.

**Viscosity**: According to Aleksandrs et al., 2016, an increase in egg yolk oil content decreases the viscosity of mayonnaise. Treatment D had the highest value, probably owing to its high level of tofu. As stated earlier, tofu is rich in cellulose which has a high mechanical strength. This property makes for thicker mayonnaise when tofu is applied as an emulsifier. Just like in emulsion stability, the combination of 25% egg yolk and 75% tofu conferred a higher viscosity to D, above the other treatments. A conflicting result was obtained by Kobra et al., 2014. They discovered egg yolk prepared mayonnaise samples had higher viscosity than samples prepared with soymilk. It was followed by treatments C (50%) and E (100%) which were statistically the same. This means the addition of egg yolk up to 50% does not significantly alter the viscosity of mayonnaise. Treatment A was also statistically the same as C, D and E. This means there was no significant difference between the viscosity of treatments A, C, D and E. Treatment B had the lowest viscosity, owing to its watery consistency and was significantly different from the other samples. Viscosity is related to the thickness of the emulsion. The more viscous a mayonnaise is, the higher its quality.

**Oil Staining**: Treatment E had the highest value. According to the definition of oil staining provided in data collection, this means that treatment E absorbed the least oil during production. This means including tofu at 100% produces mayonnaise with a relatively high oil content in its continuous phase which may predispose the emulsion to rapid lipid oxidation and reduce its stability. Mayonnaise with higher levels of oil are prone to lipid oxidation hence spoilage (Depree and Savage, 2001). It was followed by treatments D and C which were statistically the same, there was no significant difference between the amounts of oil these treatments did not absorb. Treatment B had the least value. This means that B had the most capacity for oil absorption and so will be less prone to lipid oxidation and instability. According to Ecovatec (2015), egg yolk has been shown to resist rancidity better than soy lecithin. This is due to the negatively charged nature of the phospholipids present in soy lecithin which causes the emulsion to oxidize quicker than the neutral phospholipids in egg yolk lecithin (Ecovatec, 2015).

This trend is also reflected in emulsion stability for the same treatment and as suggested earlier, might be due to the combination of both soy and egg yolk lecithin in the ratio 25:75. This result also shows that the value of oil staining is directly proportional to the value of emulsion stability. There was no significant difference between the oil staining values of treatments A, B, C and D. However, there were significant differences between treatments B, C and D. Treatments C and D had a higher value than B. This means they absorbed less oil than B and so will be more prone to instability. The higher the value of oil staining, the lower the quality of the mayonnaise.

**Film Formation**: Treatment E had the highest value and formed film the slowest. This is advantageous for mayonnaise as film formation reduces its aesthetic quality. It was followed by treatment B. Next was treatment C. It was followed by treatments A and D which were statistically the same and formed film the quickest. Using egg yolk at 100% encourages film formation which reduces the aesthetic quality of mayonnaise. This quick film forming ability of egg yolk is due to the presence of surface active proteins, mainly ovomucin, conalbumin and lysozyme. (Kuntz, 1998). The absence of these proteins in tofu may be responsible for its poor film formation.

**Elasticity**: Treatment A was the most elastic of all the treatments probably due to its high egg content. It was followed by C, next was D. Treatment B had a value of 0 due to its watery consistency and E also had a value of 0. Mayonnaise should be creamy and not elastic. The more elastic mayonnaise is, the lower its quality. The egg yolk is divided into 3 layers: the middle elastic layer, sand viscous layer and the outer layer. It is the middle elastic layer that is responsible for the elastic property of egg yolk. (Xu, et al., 2016). This elastic property is absent in tofu which may be the reason mayonnaise samples had decreasing
elasticity with increasing levels of tofu.

**Colour:** Treatment A had the most yellow colour and it was followed by treatment B, up to E. The yellowness of samples was in a descending order, with decrease in egg yolk content. This may be due to the presence of colour pigments in egg yolk. The colour of an egg yolk is from the xanthophyll carotenoids lutein and zeaxanthin. Yellow carotenoids are typically associated with birds. (Hamelin and Altemueller, 2012). They are responsible for the yellowish colour of egg yolks and as such, mayonnaise samples were increasingly yellow with increasing egg yolk content. Lutein and zeaxanthin are absent in tofu but are replaced by the compounds anthocyanins, isoflavone and polyphenol, (Evans, 1991). Which gives tofu its characteristic off-white or beige colour. This may be the reason mayonnaise samples were decreasingly yellow with higher tofu levels.

**Table 3: Colour ranking**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>Yellow</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>Yellow</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>Pale yellow</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>Very pale yellow</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>Off white</td>
</tr>
</tbody>
</table>

**Day to Syneresis:** All treatment samples showed resistance to syneresis except E. Treatment E began to show signs of partial syneresis three days after its production and completely separated six days after it was produced. All other treatments showed no syneresis but exhibited spoilage. Treatment A started showing signs of spoilage (black discolouration) after four days. Treatment B began to spoil after six days, it showed mould formation. Treatment C developed a slight odour and little spoilage after six days. Treatment D was still intact six days after production with no signs of spoilage and negligible syneresis. Although treatment E separated completely, it showed no signs of spoilage. By the tenth day, all three replicates of treatment A had spoiled completely although there was no separation before spoilage. On the seventeenth day when the experiment was terminated, two replicates of both treatments B and C were completely spoilt and no separation occurred. One replicate of treatment D was completely spoilt, one was partially spoilt while one remained intact. It still showed negligible separation. Only one replicate of treatment E showed signs of spoilage by the time the experiment was terminated. The syneresis of samples is related to their emulsion stability. The trend observed was that the rate of syneresis of samples corresponded with their emulsion stabilities. So, treatment E which had the fastest rate of syneresis also had the least emulsion stability. This may be a function of the nature of lecithin present in both egg yolk and tofu. Kobra et al., 2014 obtained a similar result using soymilk as an emulsifier in mayonnaise. They discovered that for 100% soymilk, a layer of oil was clear after 10 days but there was no marked oil separation in the case of the other samples.

**Conclusion**

Tofu is an efficient replacer of egg yolk in mayonnaise and the best level of replacement of tofu in mayonnaise is 75%.

**Reference**


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