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RHEOLOGICAL, FUNCTIONAL AND PASTING PROPERTIES OF NATIVE AND MODIFIED CASSAVA STARCH-EGG WHITE (ALBUMEN) POWDER

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Abstract— **Manufacturing of food ingredients is one of the largest sectors of the food industry especially in developed world. In developing countries, high cost of egg white powder used in baked products as a stabilizer have resulted in the search for substitute food ingredients which will serve same purpose. Starch albumen powder (SAP) is a new food ingredient that is made from blends of cassava starch and egg albumen which has been developed to serve as a replacement to egg white powder. This study analysed the rheological, functional and pasting properties of SAP processed from native and modified cassava starch. Starch was added to the albumen at 0, 5, 10, 15, and 20% (w/v) for both raw and modified cassava starch while 100% egg white was used as control. The blends were poured on a flat aluminium trays and dried in a convective air dryer at 60^{o}C for 12 hours. The results showed that aqueous SAP blends from raw and modified starches is an example of pseudoplastic which is a non-Newtonian fluid behaviour indicating that the viscosity decreased with increased shear rate whereas the 100% egg white showed a shear thinning behaviour. Power law model gave fairly good fit to the data. There was a significant difference ($p<0.05$) in the functional and pasting properties of the SAP blends. Water and oil absorption increased with increasing starch content while pasting properties improved with addition of starch. In conclusion, SAP blends from raw and modified cassava starch offers a reliable replacement for egg white powder.**

Keywords— **Egg white; Cassava starch; Albumen; Starch-Albumen powder; chemical analysis; Rheology.**

I. INTRODUCTION

Egg white is a clear liquid often called albumen which occupy about two-third of the total egg's weight out of its shell. Raw eggs are included in food formulations due to their functional properties such as foaming, coagulation, gelation and emulsification properties compared to other protein sources (Froning, 1988). Most food manufacturers use liquid egg white because it's convenient, however, it poses reduced shelf life to baked products due to the high moisture content. Egg white powder from spray drying is probably the most common form of dried egg white. Nigerian food industries need egg white powder for wider application, however, egg white powder is scarce due to high cost of the product and huge capital investment for equipment and facilities needed for production. Therefore there is a need for alternatives to be used in place of egg white powder especially in developing countries around the world.

Starch is an important food ingredient with lots of industrial applications. The most common sources of food starch are maize, potato, wheat, cassava, rice and yam. Cassava is one of the most starchy root crops in the tropics. In urban and rural areas of Nigeria, cassava serves as a staple food. Cassava starch has found applications in the food and pharmaceutical industries making cassava roots an important industrial cash crop providing source of income and livelihood to farmers.

Raw starches also yield pastes of poor stability which decreases its shelf life. In order to improve on the desirable functional properties and overcome its limitations, raw starches are often modified. Starch modification can be physical, chemical, enzymatic or biological modification. Amongst these modifications, chemical modification is the most frequently used process (Daramola and Osanyinlusi, 2006).

Food ingredients are classified based on their effect in food system. Food ingredients may be preservative, antioxidants, stabilizers, emulsifiers and gelling agents. Stabilizers and gelling agents are specifically made from carbohydrate and protein rich sources due to the gelling properties of many protein and carbohydrate molecules. In the formation of stable emulsion, emulsifying agents and stabilizers may be used (Dickson and Stainsby, 1992).

Starch-Albumen Powder (SAP) is a new food ingredient and its potentials was investigated in food systems. SAP could serves as an alternative to egg white powder in some product formulation like baked goods (Shittu et al., 2010). Nigeria rank as one of the highest producers of cassava in the world. The conjugation of cassava starch with egg albumen improved some functional properties like water and oil absorption capacity, least gelation capacity (LGC) (Shittu et al., 2010). However, the flow characteristics of aqueous suspension of SAP at various practical temperature and handling conditions needs to be determined. The data would be useful in understanding processing, packaging and handling conditions of SAP.

Therefore, the objective of this study is to determine the rheological, functional and pasting properties of native and modified cassava starch-albumen powder.

II. MATERIALS AND METHODS

A. **Materials –**

Fresh eggs were purchased from the local farm located at the federal university of agriculture Abeokuta. Cassava starch was extracted from fresh cassava roots in the food processing laboratory of the department of food science and technology, Federal university of Agriculture Abeokuta, Nigeria.

Preparation of native cassava starch

Cassava starch was prepared according to the method described by Osunsami, 1987. The cassava roots were purchased from a local farm supplied by the farmers, the cassava roots were 1-2 days old. The cassava roots were peeled using knives to remove the outer skin covering the roots. The roots were washed with clean water to remove dirt, sand and smaller peels adhering to the surface of the roots. The roots were grated using mechanical cassava grater to reduce the size and were mixed with water to give fine flowing slurries. This was filtered using a white cloth which is porous enough to remove the fibrous part of the roots which are seen as residue. The milky filtrates were allowed to settle for about 2 hours and the top water was decanted to give the starch. Water was added twice to wash the starch and this is called starch washing. This was allowed to settle again and dewatered prior to the final drying process. The cassava starch was dried for 2 days and milled into powder using a milling machine. It was packaged in an airtight container until used for analysis.

Preparation of acid modified cassava starch

Acid modification of starch was done by suspending the native starch (500g) in 100 ml of 6 % w/v aqueous hydrochloric acid at room temperature for 24 hours without stirring. After hydrolysis, the suspension was neutralised with 0.2 M sodium hydroxide solution, the reaction was terminated on attaining a pH of 7 using the pH meter. The starch slurry was washed 3 times with distilled water and the water was decanted. The acid modified starch was dried in hot air oven at 60^{o}C for 18 hours and then powdered using a laboratory milling machine and stored in an airtight container.

Preparation of starch albumen powder (SAP)

SAP was prepared according to the method as described by Shittu et al. (2010). The fresh eggs were washed and carefully broken to avoid the inclusion of foreign materials in the egg content. The albumen (egg white) was carefully separated from the yolk using a kitchen type cup strainer to avoid contamination by the egg yolk. Cassava starches (native and modified) were added to albumen at 0, 5, 10, 15, and 20 % (w/v) and mixed in a laboratory electric blender at medium speed for 60 seconds within which complete homogenization was achieved. The blends were poured on a flay aluminium tray to a thickness of about 0.3 cm and were dried in a fabricated convective air dryer at a temperature of 60^{o}C for 4 hours and a constant air velocity of 0.3 m/s to form flakes. The flakes were cooled and blended into powder. The powder was sieved through a 60 mesh screen to give a finer powder that was used for analysis.

B. **Methods –**

Moisture content determination

Moisture content was determined using the method of AOAC (2005). Plantain sample (5 g) was weighed into a pre-weighed clean dried dish, after which the dish was placed in a well-ventilated oven (UF55 Memmert Oven model) maintained at 103 ± 2^{o}C for 16 h. Transferred to the desiccator at room temperature to cool. After cooling for about 30min, it was weighed as quickly as possible. The loss in weight was recorded as moisture.

$$\text{Moisture content} \quad \frac{M_1\text{-}M_2 \times 100}{M_1\text{-}M_0}$$

Where M_o = Weight in g of dish
M_1 = Weight in g of dish and sample before drying
M_2 = Weight in g of dish and sample after drying
Note that M_1-M_0 = weight of sample prepared for drying

Water absorption capacity

This was determined according to Solsulski (1962). Each of the flour blend (1 g) was weighed and 15 ml distilled water was added in a weighed 50 ml centrifuge tube. The tube was agitated on a vortex mixer for 2min and centrifuge at 4000 rpm for 20 min. The clear supernatant was decanted and the volume was measured and discarded. The adhering drops of water were removed and the tube reweighed. Water absorption capacity was expressed as the weight of water bound by 100 g dry flour.

Oil Absorption capacity

Oil absorption capacity (OAC) was determined according to the method of Solsulski et al., (1976). To 1 g of the flour, 10 ml of refined corn oil was added in a weighed 50 ml centrifuge tube and agitated on a vortex mixer for 2 min and centrifuged at 4000 rpm for 20 min. The volume of the free oil was recorded and discarded. The tube was weighed with the content. Oil absorption capacity was expressed as ml oil bound by 100 g dry flour.

Least gelation capacity

The method of Coffman and Garcia (1977) was used. Sample suspension of 2-20 % (w/w) were prepared in 5 ml distilled water. The test tubes containing these suspension were heated for 1 hour in a boiling water bath followed by rapid cooling under cold running tap water. The test tubes were further cooled for 2 hours at 4^{o}C. The least gelation concentration (LGC) is that concentration when the sample from the inverted test tubes does not fall or slip.

Pasting properties determination

The pasting characteristics of the flour samples was determined using a Rapid Visco Analyzer (Model RVA-Super 4, Newport Scientific Perten Instruments AB, Huddinge, Sweden) interfaced with a personal computer equipped with the Thermo cline software supplied by same manufacturer. About 3 g of flour samples (moisture content already determined to be less than 12%) were weighed into a canister and made into slurry by adding 25 ml of distilled water. This canister (covered with a stirrer) was inserted into the RVA. The heating and cooling cycles were automatically programmed in the following manner. The temperature was kept within 60 to 99^{o}C while maintaining a rotation speed of 160 rpm. The whole cycle was completed within 13 min. The viscosity was expressed in Centipoises (cp). The following parameters were determined automatically by the instrument: peak viscosity (the maximum viscosity during pasting), breakdown viscosity (the difference between the peak viscosity and the minimum viscosity during pasting), setback viscosity (the difference between the maximum viscosity during cooling and the minimum viscosity during pasting), final viscosity (the viscosity at the end of the RVA run), pasting temperature (^{o}C) (the temperature at which there is a sharp increase in viscosity of flour suspension after the commencement of heating) and peak time (min) (time taken for the paste to reach the peak viscosity) .

Rheological experiment

The rheology study was conducted by Brookfield viscometer which was used to determine the effect of shear rate and temperature on the viscosity of aqueous gel of SAP. The sample solution was prepared by rehydrating SAP at a constant powder to water ratio of 5 % (w/v) at 60^{o}C. Effect of shear rate (5, 10, 20, 30, 50, 60 and 100 rpm) and temperature (60^{o}C) on the viscosity of aqueous gel of starch albumen powder was measured using spindle number 2.

Fig. 1. Brookfield Viscometer

Statistical and experimental data analysis

The experimental data was fitted into the power law model:

$$\sigma = K\gamma\hat{}n$$

σ = Shear stress, γ = Shear rate, n = flow behaviour index and K = consistency index

Nonlinear regression analysis was used to determine the values of the parameters in the equation above. The means of the experimental data from the above were separated by performing Duncan's multiple range test (DMRT). The Microsoft excel 2007 spreadsheet and statistical package for social scientist version 16.0 (SPSS Inc. Chicago, IL) were used in the analysis.

III. RESULTS AND DISCUSSION

Rheology properties

The rheological properties of cassava reconstituted 100 % albumen powder, native SAP and acid modified SAP samples are presented graphically in figure 2 and 3 respectively.

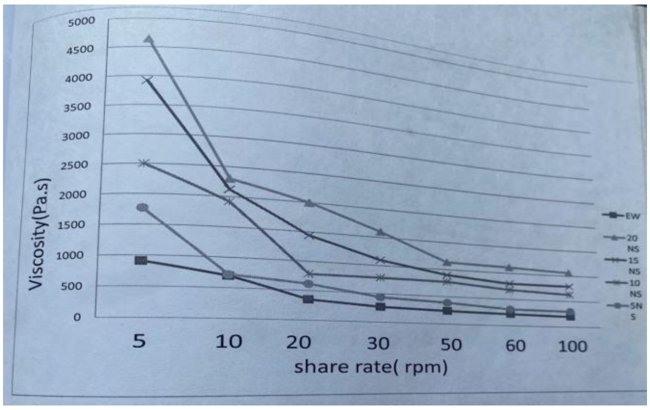

Fig. 2. Effect of shear rate on the viscosity of SAP pastes from native starch. Starch: Albumen of 5:95 (5 % NS), 10:90 (10 %NS), 15:85 (15 % NS), 20:80 (20 % NS), 100% EW, NS= Native starch, EW= Egg white

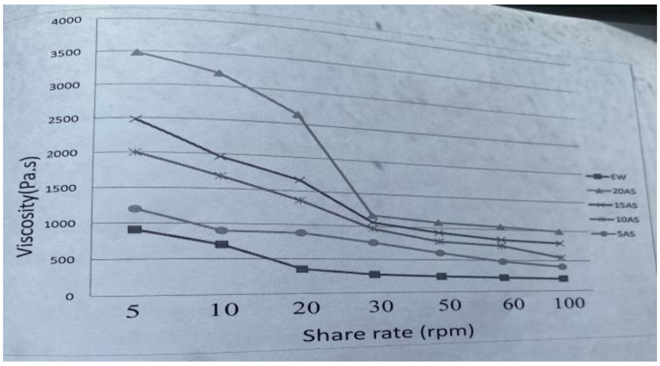

Fig. 2. Effect of shear rate on the viscosity of SAP pastes from acid modified starch. Starch: Albumen of 5:95 (5 % AS), 10:90 (10 %AS), 15:85 (15 % AS), 20:80 (20 % AS), 100% EW, AS= Acid modified starch, EW= Egg white

Generally, viscosity of the reconstituted egg white powder decreased with increased shearing rate at the constant temperature used for the experiment. Therefore, it behaves like a shear thinning substance. Gossett et al. (1983) reported a shear thinning behaviour for raw egg albumen. However, the paste from all SAP samples from both native and modified starch showed a shear thinning behaviour showing a decreased viscosity with increased shearing rate. Regardless of the level of starch substitution, the viscosity reduced with constant temperature in samples. Starch paste itself is a shear thinning food material (Thebaudin et al., 1998); Martinez et al., 2003). This result indicates that the flow behaviour of SAP paste from the native and modified starch is more influenced by the presence of starch than albumen. The decrease in viscosity with increased shear rate could be explained to be due to the progressive deformation thereby offering less resistance to flow (Pal, 1996).

The flow behaviour index (n) values for the SAP pastes from native and modifies starches are showing in table 1. These values ranged from 0.256 to 0.429 and 0.541 to 0.683 for SAP made from native and modified starches respectively. The values of the flow behaviour were lower than 1 indicating pseudoplastic behaviour of the different samples. The flow behaviour indices decreased with increased starch concentration for SAP samples from modified starch. However, irregular changes in flow behaviour indices was observed for SAP samples from native starch. The 100 % egg white had a flow behaviour index value of 0.406 which is less than 1 indicating a pseudoplastic behaviour.

The consistency index (K) values for SAP pastes from native and modified starches are shown in table 1. The consistency index is a measure of composite internal friction of molecules undergoing shearing forces. The K values increased with increased starch content at 60^{o}C. The power law gave a fairly good fit to the data. The values of multiple correlation coefficient (R^2) ranged between 0.929 to 0.976 and 0.863 to 0.968 for SAP samples from native and modified starches respectively.

Table -1 Consistency index, flow behaviour index and multiple correlation coefficient of native and acid modified starch albumen pastes using power law model

Sample	Consistency index (K)	Flow behaviour (n)	Multiple correlation coefficient (R^2)
100 % Egg white	2420.40	0.406	0.967
SAP(Native starch)			
5 % NS	5482.15	0.256	0.931
10 % NS	6317.10	0.429	0.929
15 % NS	10956.18	0.338	0.976
20 % NS	11109.66	0.418	0.942
SAP(Modified starch)			
5 % AS	2009.60	0.683	0.934
10 % AS	3997.61	0.597	0.968
15 % AS	4929.83	0.588	0.964
20 % AS	7930.19	0.541	0.863

Moisture content

The moisture content of SAP samples on dry weight basis from native and modified starches are presented in figure 4. The moisture content of the SAP samples ranged from 8.48 to 10.56 % and 8.36 to 10.66 % for native and modified starches respectively. There were significant differences (P<0.05) in the moisture content of SAP as starch content increased. The moisture content of 100 % egg white was 8.37 %, Indicating that the product could be regarded as a dried product.

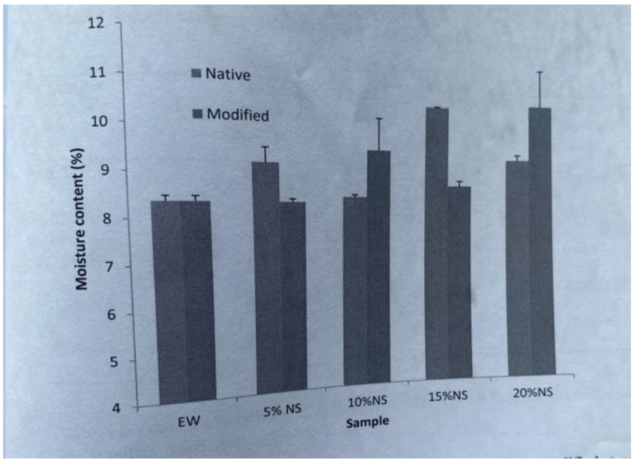

Fig. 2. Moisture content of the SAP samples from native and modified starches

Functional properties

The functional properties of SAP from native and modified starches were presented in table 2. The water absorption capacity (WAC) of the SAP samples showed a significant difference (P<0.05). The WAC values ranged from 1.39 to 2.88 g/g and 0.73 to 2.20 g/g for SAP from native and modified starches respectively. The results suggest that the percentage starch inclusion had an incremental effect on the WAC values of the SAP samples from native and modified starch (Shittu and Ikpasa, 2006). The WAC of the 100 % egg white powder had a value of 0.94 and is closely similar to that of the SAP samples from native and modified starches. The major chemical compositions that enhanced the water absorption capacity of the SAP samples are proteins and carbohydrates, since these constituents contain hydrophilic parts, such as polar or charged side chains (Yusuf et al., 2008). The oil absorption capacity (OAC) of the SAP samples showed a significant difference (p<0.05) for both native and modified starches. The OAC values ranged from 0.70 to 1.30 g/g and 0.87 to 1.95 g/g for native and modified starches respectively. OAC is important since oil acts as flavour retainer and increases the mouthfeel of foods (Aremu et al., 2007). The results suggest that the percentage starch inclusion has an incremental effect on the OAC of SAP samples for native and modified starches. The OAC of 100% egg white powder had a value of 0.78 g/g. The OAC of the SAP samples from native and modified starches were higher than that of egg white powder.

The least gelation concentration (LGC) which is defined as the lowest powder concentration at which gel remained in the inverted tube was used as index of gelation capacity. The lower the LGC, the better the gelation ability of the protein ingredient (Akintayo et al., 1999). The results indicated that the gelation of the SAP samples from the native and modified starches were best at concentration 8 % and 10 % respectively. This implies that addition of starch enhanced the process of gelation in egg white powder indicating that SAP samples require a low concentration for gel formation and may find useful application in food systems such as sausage emulsion, custard type pudding and sauce, which require thickening and gelling. Variation in gelation values obtained might be linked to the relative ration of different constituents such as proteins, carbohydrates and lipids (Aremu et al., 2007).

Table -2 Functional properties of native and modified starch albumen powder

Sample	Water Absorption Capacity (g/g)	Oil Absorption Capacity (g/g)	Least Gelation Capacity (%)
100 % Egg white	0.94±0.02^{e}	0.78±0.05^{a}	9.00±1.14^{a}
SAP (Native starch)			
5 % NS	1.39±0.03^{b}	0.70±0.07^{ac}	8.00±0.00^{a}
10 % NS	1.71±0.06^{a}	0.89±0.00^{ab}	9.00±1.14^{a}
15 % NS	2.19±0.02^{c}	0.95±0.05^{b}	8.00±0.00^{a}
20 % NS	2.88±0.02^{d}	0.95±0.05^{b}	10.00±0.00^{a}
SAP (Modified starch)			
5 % AS	0.73±0.00^{b}	0.87±0.05^{ab}	8.00±0.00^{a}
10 % AS	1.22±0.00^{d}	0.97±0.04^{b}	9.00±1.14^{a}
15 % AS	1.44±0.02^{a}	0.98±0.13^{ac}	8.00±0.00^{a}
20 % AS	2.20±0.10^{c}	1.95±0.39^{b}	10.00±0.00^{a}

Values are means of triplicates. Mean values having different superscripts within same column are significant differences (P<0.05).

Pasting properties

The pasting properties of SAP samples from native and modified starches are presented in table 3. The three main important viscosity parameters are peak, breakdown and final viscosity. All these parameters were evaluated using a rapid visco analyzer (RVA) giving the values of the various viscosities in RVU. Gelatinization and pasting are series of changes that starchy foods heated in an aqueous environment undergoes. These are two of the most important properties that influence the quality and aesthetic consideration in the food industry, since they affect texture and digestibility as well as the end use of starch foods (Adebowale et al., 2005). The peak viscosity of SAP samples ranged from 138.50 to 305.83 RVU and 161.55 to 377.67 RVU for native and modified starches respectively. The 100 % egg white powder had the highest peak viscosity of 468.92 RVU. Final viscosity indicates the ability of a material to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring. Final viscosity of the SAP samples ranged from 232.50 to 442.17 RVU and 168.75 to 441.83 RVU for native and modified starches respectively.

Table -3 Pasting properties of native and modified starch albumen powder

Sample	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Set back Viscosity (RVU)	Peak Temp. (^{o}C)
100%Egg white	468.92^{d}	173.42^{b}	295.50^{d}	190.50^{a}	17.08^{a}	86.45^{c}
SAP (Native starch)						
5 % NS	305.83^{d}	244.58^{d}	61.25^{d}	273.58^{c}	29.00^{b}	91.95^{b}
10 % NS	138.50^{a}	122.75^{a}	15.75^{a}	232.50^{b}	109.75^{c}	94.80^{a}
15 % NS	292.33^{c}	257.42^{a}	34.92^{c}	442.17^{d}	184.75^{d}	86.35^{c}
20 % NS	237.42^{b}	205.00^{c}	32.420^{b}	312.17^{d}	107.17^{c}	77.45^{d}
SAP (Modified starch)						
5 % AS	377.67^{c}	282.33^{d}	95.33^{c}	441.83^{d}	159.50^{d}	92.75^{a}
10 % AS	343.17^{b}	247.67^{c}	95.50^{b}	426.83^{c}	159.50^{d}	87.15^{b}
15 % AS	321.83^{c}	237.42^{d}	84.42^{c}	311.75^{d}	74.33^{d}	78.35^{d}
20 % AS	161.58^{a}	117.17^{a}	44.42^{a}	168.75^{b}	51.58^{b}	76.60^{e}

Values are means of triplicates. Mean values having different superscripts within same column are significant differences ($P<0.05$).

The final viscosity of 100 % egg white powder was 190.50 RVU which was lower than the values of SAP samples, indicating that the viscosity of the egg white can be improved by inclusion of starch.

Breakdown values of SAP ranged from 15.75 to 61.25 RVU and 44.42 to 95.33 RVU for native and modified starches respectively while set back values ranged from 29.00 to 184.75 RVU and 51.58 to 159.50 RVU for native and modified starches respectively. The breakdown and set back values for 100 % egg white were 295.50 RVU and 17.08 RVU. Peak and break down viscosity indicates a measure of the stability of starches measuring starches with high resistance to break down while set back viscosity indicates lower retrogradation tendency and vice versa (Oduro et al., 2000). The SAP samples had a lower breakdown viscosity but higher set back viscosity when compared to the 100 % egg white powder. Pasting temperature gives as indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is measured. It ranged from 77.45 to 91.95^{o}C and 76.60 to 92.75^{o}C for SAP samples from native and modified starches. The 100 % egg white powder recorded a pasting temperature of 86.45^{o}C. Numfor et al. (1996) reported that a higher pasting temperature implies higher water binding capacity and gelatinization due to a high degree of association between starch granules.

IV.CONCLUSION

The data obtained depicts that gel of native and acid modified starch-albumen powder is an example of pseudoplastic non Newtonian fluids which indicated that viscosity decreased with increased shear rate. Starch had more significant effect on the rheological behaviour of the SAP samples than albumen. The power law model gave a fairly good fit to the data.

Modification of the starch properties prior to inclusion in egg white caused varying adjustment in the functional and pasting properties. The water and oil absorption, least gelation capacity increased with increasing starch content from native and modified starches. Addition of starch enhanced the process of gelation indicating that the SAP samples required a low concentration for gel formation. The results showed the SAP samples could serve as substitute to egg white powder in terms of the rheological, functional and pasting properties.

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