PRINCE ABUBAKAR AUDU UNIVERSITY, ANYIGBA KOGI STATE, NIGERIA

THIRTEENTH (13^{TH}) INAUGURAL LECTURE

FOOD RESEARCH INNOVATIONS AS PANACEA FOR POST-HARVEST LOSSES, FOOD SECURITY AND SAFETY: RENOWN CONTRIBUTIONS OF A CERTIFIED FOOD SCIENTIST

BY

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Thirteenth (13^{th}) Inaugural lecture

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National Anthem

Nigeria, we hail thee,
Our own dear native land,
Though tribes and tongues may differ,
In brotherhood we stand,
Nigerians all, are proud to serve
Our sovereign Motherland.

II

Our flag shall be a symbol
That truth and justice reign,
In peace or battle hounour'd
And this we count as gain,
To hand on to our children
A banner without stain.

III

O God of all creation,
Grant this our one request.
Help us to build a nation
Where no man is oppressed,
And so with peace and plenty
Nigeria may be blessed
National Pledge

Prince Abubakar Audu University Anthem

Prince Abubakar Audu University,
you stand in strength and pride.
Showing the way for all who yearn
Standing firm in wisdom and truth
In unity we grow

Committed to Imparting Knowledge,
Skills and learning
To all who long for excellence
Prince Abubakar Audu University, the
pride of the World
We honour your virtues.

Preceding Inaugural Lectures of Prince Abubakar Audu University, Anyigba

S/N	Inaugural Lecturers	Title	Date
1	Professor Sunday S. Arogba	Phenolics: A Class of Nature's Chemical Weapons of Self-Preservation	Tuesday, 26th August 2008
2	Professor Zacchaeus O. Apata	Unburdening the Colonial Burden: Lessons from History	Tuesday 17th August 2010
3	Professor Steve Metiboba, Jp	Matrimony between two Healthcare Systems: An Unholy Wedlock?	Monday, 27th June 2014
4	Professor Stephen I. Ocheni	Accounting for Public Funds: The Leviathan of Government Bureaucracy	Monday, 25th June 2018
5	Professor Eniolorunda A. Tai Oluwagbemi	Scientific Elegance and Political Naivety of Food and Wood Sufficiency In Nigeria: The Take of An Agroforester	Thursday, 28th June 2018
6	Professor Charles I. Oyewole	Coroner's Inquest: An autopsy of the Man with the	15th August 2019

		Hoe	
7	Professor Odin Eboh Monday	Insanity and Life Pain Two Ancestral Curses: The Role of Village Herbalist	24th August, 2019
8	Professor Jimoh Habibat Isah	The Geography of Erosion in Nigeria: An Explanation	30th August, 2019
9	Professor Marietu Ohunene Tenuche	Neoliberalism: Forecasting Nigeria's Ungodly Romance with the East	29th September, 2020
10	Professor James Omale	Remedy or Poison? Double –Edge Sword PARADOX OF Alternative Medicine: The concern of Toxicologist.	11th March, 2021
11	Prof. Stephen Jimoh Ibitoye	If Agricultural Revolution is the Answer, What is the Question?	20th September, 2022
12	Prof. Enejo Simon Attah	Intercropping: That there may be Enough Food	19th February, 2025

Protocol

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Preamble

This is the day God has made and I am glad in it. I give Jehovah Elohim (God Almighty) all the glory and honour for counting me worthy for today's inaugural lecture. I appreciate greatly the honour given to me by the Vice-Chancellor to deliver the 13th Inaugural lecture of our great University, Prince Abubakar Audu University, Anyigba, which is the first ever in the Department of Food, Nutrition and Home Sciences and fifth in Faculty of Agriculture. According to authoritative Oxford Dictionary, Professor's Inaugural lecture simply refers to first official lecture delivered, marking the beginning of the attainment of that academic rank and to show-case professorial achievements for recognition, especially in the university system.

This lecture therefore, shall focus on modest contributions to food research in my academic sojourn (over two decades) in the aspects of innovative food storage technology, processing and packaging of some indigenous/native food commodities (plant and animal-based) and by-products/wastes conversion and utilization.

1.0 Introduction

1.1 Meaning of food, sources and importance

Food is defined as any matter that people or animal can eat to supply energy and furnish body nutrition including drinks, but not water. It also means a component of nutrients (protein, carbohydrates, fats, vitamins and minerals) consumed, digested and ultimately utilized to meet the body needs. Plants and animals are the commonest sources of food, while derived foods are analogues to mimic the natural food. They are also made up of other constituents including antioxidants, flavourants, pigments, health phytochemicals. Typical examples of plant food commodities include: roots and stem tubers, fruits and vegetables, nuts and oil seeds; sugar cane and beet, cocoa, coffee, herbs/spices, while flesh/animal foods include macro-livestock (large and small animals), poultry, mini-livestock (termites, crickets, grasshopper, frogs).

Food product on the other hand refers to primary (finished) and secondary (semi-finished) food obtained from raw food materials which is a complete item, appropriately packaged to reach the consumer(s)/user(s) in its best quality condition. It could be new, already existing or improved (Orishagbemi, 2024). Examples of food products include canned meat, fish, milk, egg powder, corn flakes, wheat flour, yam chips, kunu zaki, yoghurt dry mix, food beverages, baked products (bread, biscuits).

1.2 Food research and innovation

Food research simply means a close and careful scientific study of food for finding out new facts or information, while innovation is the introduction or discovery of new ideas or ways of doing something. For this lecture, food research and innovation shall apply to the scientific study, introduction and discovery/invention of new food preservation (processing and storage) technologies especially for indigenous raw commodities native to Nigeria.

Major purposes include:

i. reduction of high postharvest losses usually experienced by farmers, especially at the peak of season for raw plant food commodities.

ii. Extension of shelf life and improved stability of raw produce and processed products.

iii. For the production of value added products such as finished/primary products ready for consumption; secondary products (industrial ingredients) as export products for import substitution.

iv. To spread availability of seasonal commodity.

v. Enhancement of diversified products from raw commodity.

vi. Maintenance of products quality in terms of wholesomeness, safety, nutritive values, packaging, sensory and consumer acceptance.

vii. To enhance economic benefits (generate income and create employment in food & related industries)

viii. For further technological researches.

1.3 Food Research and Development (R&D)

This could be basic, applied, contract or collaborative. The basic R&D requires scientific laboratory bench works, observations, experimentation using the fundamental pure sciences, engineering and technology and the results are invariably used for applied research works to solve particular or peculiar problems, to achieve new inventions and discoveries (innovation). Contract food research involves food industries, usually targeted at solving peculiar technological problems, while collaborative research is multidisciplinary in nature, involving experts from various food and related disciplines (Food scientists, Engineers, Economists, Agriculturists including crop, animal, fishery, agricultural economic/extension experts.

1.4 Postharvest food losses

This refers to losses of food materials (both quantitative and qualitative) that occur immediately after harvesting/slaughtering and before getting to the consumer's table (in various forms). Losses occur at the farm gates, packing houses, market places, other distribution channels as results of spoilage and deterioration. In Nigeria, 30-40% annual postharvest losses of food crop commodities produced have been reported severally (Orishagbemi, 2016; RMRDC, 2010).

1.5 Food Security and safety

It is explained as access by all people at all times to enough food (in quantity and quality) all the year round for an active healthy life. Also means access to sufficient, safe and nutritious food at all times by individuals (MFNP, 2016). In Nigeria, it is obvious there is food insecurity, which was why the President in September, 2023 declared state of emergency on food security in the country by putting in place several strategies to beef-up our food security. Lack of adequate storage technology/facilities and basic preservation techniques have been highlighted among some factors responsible for the state of food insecurity. For instance, about 30-40% annual postharvest loss of plant food commodities (crops) produced in Nigeria occurs to further reduce insufficient quantities that are available (Orishagbemi, 2016). Food is safe when it does not constitute any health risk to the consumer. It is free from contaminants and toxicants (microbial, chemical, heavy metals, non-metals, pathogens, allergens) which can cause food poisoning, intoxication and they are destroyed during conversion processes prior to food consumption.

2.0 Food preservation Research innovations

2.1 Storage of fresh, raw plant food commodities

Vice-Chancellor Ma, the following storage technologies have been applied and used in my research works to preserve some indigenous fruits as fresh raw commodities to extend shelf life, retain freshness, nutrients and sensory attributes.

A. Modified Atmosphere Storage (MAS) and Packaging (MAP): This is a type of storage system whereby climacteric fruits/vegetables, such as mature green unripe mango, plantain, banana, guava, pawpaw, tomato are enclosed in a sealed chamber without controlled atmosphere condition involving natural manipulation of oxygen (O_2) and carbondioxide (CO_2) concentrations under low temperatures and high relative humidity. The principle or mechanism:In the sealed space or chamber O_2 is consumed by the respiring fruits to reduce its level while CO_2 increases. Reduced O_2 concentration and increased CO_2 regulate/reduce the respiration rate of the stored fruits and vegetables, leading to delay of ripening which enhances shelf-life (also known as storage life). This storage technique is known as controlled atmosphere storage (CAS) when O_2 and CO_2 concentrations are controlled, also temperature and relative humidity (this is hi-tech storage technique which is very expensive to operate and maintain).

Advantages of MAS include: extension of storage life of fresh fruits beyond their limit in air at tropical ambient temperature by delaying ripening (climacteric fruits), enhances quality than if stored in air, have attractive appearance, better taste, texture, aroma and less disorders, extension of marketing especially during off-season; controls disease infections and attack by vernims; less expensive to operate and maintain; practicable in the rural areas by farmers/processors. In my works, the storage of green mature plantain and mangoes in modified atmosphere/environment storage (MAS/MES) and modified atmosphere packaging were reported (Orishagbemi and Olorunda, 2007; Odeja and Orishagbemi, 2009). Mature green plantain (*Musa parasidiaca*, Bini variety) kept for 38 days and mangoes (*Mangifera indica*, local variety) for 48 days with shelf-life extension of 20 and 43 days respectively. For instance, plantain freshness, nutrient and sensory properties were retained upon normal ripening when exposed to natural air (Tables 1a, b and c).

The shelf-life of mature green plantain varied with storage loads, heavier load had longer delay in onset of ripening and greater storage life extension (20 days for 90 kg plantain load in MES), while onset of ripening in air storage did not vary appreciably with loads 6±1 days recorded. Delay in ripening is due to reduced respiration, oxygen tension and elevated carbon dioxide to make subsequent respiration slower according to the heaviness of the loads. Plantain fingers in MES did not lose weight and remained fresh, while 8.70 – 9.8% weight loss occurred under open air storage. The little or no weight loss was possible due to occurrence of high relative humidity (86% RH) in the storage chamber as a result of moisture condensation on the inside wall of the polythene used to build chamber. Also freshness of plantain was maintained even after removal from storage chamber, which is enhanced by high relative humidity in MES. The plantain fingers stored in ordinary air at 53% R.H lost much water and became hard with dry skin and hence unattractive. Pulp to peel ratio values before storage (1:0.720) and immediately after removal (1:0.726) did not differ significantly (P>0.05) which increased to 1:0.670 on exposure for 2 days, showing commencement of ripening as revealed by visual yellow peel colour.

The sensory attributes (colour, texture, flavor, taste and acceptability) of both boiled and fried plantain pulp stored in MES compared favourably well with fresh market samples. This type of MES facility is a friendly and suitable intermediate storage option which could be used by farmers on the farm, at home and also plantain processors/retailers.

Table 1a: Shelf-life of green mature plantain under different loadings of modified environment storage and normal air storage(Orishagbemi and Olorunda, 2007)

Wt (Kg.) before storage	1st batch		2nd batch		3rd batch		4th batch		5th batch	
	MES	AS	MES	AS	MES	AS	MES	AS	MES	AS
	15	15	30	30	45	45	60	60	90	90
Storage duration before the onset of ripening (days)	9	6	12 5		14	5	16	6	20	6
Shelf-life extension (days)	3		7		9		10		14	

MES - Modified Environment Storage; AS - Air Storage

Table 1b: Changes in the weight and pulp to peel ratio of plantain under modified atmosphere and air storage

		1st batch		2nd batch		3rd batch		4th batch		5th batch	
Weight (kg)	Before Storage	MES 15	AS 15	MES 30	AS 30	MES 45	AS 45	MES 60	AS 60	MES 90	AE 90
	Immediately after removal from storage	14.66	13.68	29.31	27.45	43.96	40.00	58.08	54.02	86.82	81.03
	Loss	0.34	1.32	0.69	2.55	1.04	4.10	1.92	5.98	3.18	8.97
Average pulp:peel ratio	Before storage	1.39(±0.08)	1.39 (±0.06)	1.35(±0.07)	1.37(±0.04)	1.37(±0.10)	1.37(±0.07)	1.36(±0.03)	1.36(±0.03)	1.37(±0.02)	1.37(±0.06)
	Immediately after removal from storage	1.41(±0.07)	1.40(±0.09)	1.34 (±0.05)	1.36(±0.02)	1.37(±0.07)	1.38(±0.02)	1.37(±0.08)	1.40(±0.08)	1.38(±0.01)	1.39(±0.02)
	2 days after removal from storage	1.49(±0.02)	1.51(±0.04)	1.47(±0.08)	1.49(±0.10)	1.46(±0.04)	1.48(±0.10)	1.48(±0.03)	1.51(±0.03)	1.50(±0.05)	1.52(±0.07)

MES - Modified Environment Storage; AS - Air Storage

Table 1c: Mean sensory scores of boiled plantain pulp obtained from MES and AS

Sensory attributes	1st batch		2nd batch		3rd batch		4th batch		5th batch		Control
	MES 15	AS 15	MES 30	AS 30	MES 45	AS 45	MES 60	AS 60	MES 90	AS 90	
Visual colour	6.8^{a}	6.4^{a}	6.7^{a}	5.98^{a}	6.9^{a}	6.3^{a}	6.9^{a}	6.3^{a}	6.9^{a}	6.2^{a}	6.8^{a}
Flavour/ taste	5.7^{b}	4.4^{d}	5.7^{b}	4.5^{e}	6.0^{b}	4.7^{c}	5.9^{b}	4.3^{e}	6.0^{b}	4.6^{e}	5.7^{b}
Texture	6.4^{d}	5.6^{d}	6.8^{d}	5.5^{d}	6.9^{d}	5.6^{d}	6.8^{d}	5.7^{d}	7.0^{d}	5.9^{d}	7.0^{d}
Acceptability	6.8^{d}	5.5^{d}	6.7^{c}	5.6	6.6^{c}	4.9	6.8^{d}	5.3	6.9^{d}	5.4	6.9^{d}

Means with the same superscript along the same row are not significantly different (P>0.05). Values represent average of ten scores; MES - Modified Environment Storage; AS - Air Storage

Table 1d: Mean sensory scores of fried plantain pulp (firm ripe) obtained from MES and AS

Sensory attributes	1st batch		2nd batch		3rd batch		4th batch		5th batch		Control
	MES 15	AS 15	MES 30	AS 30	MES 45	AS 45	MES 60	AS 60	MES 90	AS 90	
Visual colour	7.0^{a}	6.7^{a}	6.8^{a}	7.0^{a}	6.9^{a}	7.0^{a}	7.0^{a}	6.9^{a}	7.0^{a}	6.7^{a}	7.0^{a}
Flavour/taste	6.6^{e}	5.0^{e}	6.7^{e}	4.8^{e}	6.7^{c}	4.9^{f}	6.9^{f}	5.0^{e}	7.0^{e}	4.7^{f}	6.9^{e}
Texture	6.8^{c}	4.4^{d}	6.7^{d}	4.3^{d}	7.0^{c}	4.0^{d}	7.0^{c}	4.2^{d}	7.0^{c}	4.1^{d}	7.0^{c}
Acceptability	6.9^{d}	4.6^{d}	6.8^{d}	4.2^{h}	6.9^{g}	3.9^{h}	6.8^{d}	4.3^{h}	6.9^{d}	4.4^{h}	6.9^{d}

Means with the same superscript along the same row are not significantly different (P>0.05). Values represent average of ten scores. MES - Modified Environment Storage; AS - Air Storage

B. Waxing storage technique: This involves the use of edible waxes to coat fruits/vegetables to reduce rate of respiration, prevent shriveling, shrinkage, moisture loss and retain freshness and nutrients. Such waxes include Brite Ap40 wax, paraffin, carnauba, vegetable oil, sheabutter and combination of waxes. As part of my work, investigation was carried out on the effects of different edible fats and oils on the physiological and sensory properties of some tropical fruits in storage (Orishagbemi *et al*.,2008).Firm ripe fruits of banana (Dwarf Cavendish), avocado (local variety), sweet orange (improved variety), mango (cheri variety) and cashew apple (yellow skin variety) were obtained, preserved by waxing method. Sample of each fruit commodity was prepared and waxed separately with four (4) different edible fats/oils (sheabutter – SHB; bleached palm oil BPO; vegetable oil – VGO and animal fat – ANF) and unwaxed fruit as control. Experimental samples were in triplicate which were kept in storage for seven days at tropical ambient conditions. Post storage weight and vitamin C losses and sensory attributes were determined.

The use of SHB, ANF and VGO substantially prevented weight loss by not more than 10% on the fruits except cashew apple. Most vitamin C content (65 – 87.5%) was retained in avocado, sweet orange and banana by waxing with SHB and BPO. While reduction in brix level, pH values of the fruits followed the same pattern, SHB and BPO waxes contributed the least reduction in sweet orange, mango and brix level of avocado was unaffected (Tables 2a, b, c and d). Ability of SHB and ANF to effect least weight reduction in fruits could be attributed to their viscous nature, which was able to block fruit cell pores (stomata) more than other edible fats, leading to most reduced respiration rate and least moisture loss (shriveling). On the other hand, avocado, sweet orange and mango had thicker peels than ripened cashew apple which, thereby were able to serve as barrier to prevent the juicy flesh from losing moisture easily by evaporation. These fruits also, were likely to contain less respiratory cell pores on the surface.Both BPO and SHB are able to prevent vitamin C loss mostly in avocado, sweet orange and banana which could be explained to mean that they contained some traces of antioxidants to compliment vitamin C, unlike VGO and ANF where loss of vitamin C in passion and citrus fruits was preserved by coating with commercial wax in combination with fungicidal wash. Sheabutter and vegetable oil were found to preserve the peel colour, texture, taste and flavor/aroma of banana, sweet orange, mango and avocado with no significant difference ($P>0.05$) between fresh, unstored ripe fruits.

The peel colour retained in ripened fruits due to waxing was attributed to injury-free and thick peel while thin skin or peel especially cashew apple could not withstand injury regardless of the nature of wax. Texture retention in coated whole fruits might be due to reduced respiration caused by edible fat wax especially SHB, VGO, ANF which did not permit further hydrolysis or breakdown of complex molecules including cell wall, pectin in ripened fruits. Retained taste/flavor in waxed fruits was an indication that reduced respiration in fruits due to waxing did not lead to any *in-situ* anaerobic fermentation of soluble sugars in ripened fruits under storage and thus, deterioration or spoilage had not occurred, thereby extending shelf-life of ripened fruits.

Therefore, the use of BPO, SHB and VGO as wax for sweet orange has been found suitable, also SHB and VGO for ripened mango and banana and BPO, SHB and VGO for avocado to extend short shelf-life (with nutrients and sensory qualities comparable to the fresh fruits) by seven days through the duration of distribution and consumption (similar to using hydro-cooled delivery vans).

Table 2a: Weight loss (%) of waxed fruits kept under tropical ambient storage conditions (27±2ºC; 71% RH) for seven days (Orishagbemi *et al*., 2008**)**

Coating agent	Ripened fruit samples				
	Avocado pear	Cashew apple	Sweet orange	Mango	banana
Bleached palm oil	8.9[a](0.11)	52.7[c](0.04)	10.1[e](0.01)	11.7[g](0.21)	22.0[i](0.18)
Sheabutter	4.9[a](002)	44.4[c](0.23)	8.4[e](0.01)	6.5[h](0.12)	17.4[i](0.11)
Vegetable oil	10.5[a](0.05)	59.9[c](0.07)	9.5[e](0.02)	10.15[g](0.03)	18.8[i](0.05)
Animal fat	12.0[a](0.10)	33.2[d](0.08)	5.3[f](0.06)	5.8[h](0.11)	14.7[i](0.07)
Unwaxed fruit	22.5[b](0.04)	66.1[c](0.01)	12.6[e](0.06)	8.8[g](0.03)	23.1[i](0.02)

Values expressed as average of 3 determinations (±standard error of the mean, SEM). Values in a vertical column with the same suffix letter are not significantly different (p>0.05)

Table 2b: Vitamin C contents of coated fruits kept under tropical ambient storage conditions (27±2ºC; 71% RH) for seven days (mg/100g)

Coating agent	Ripened fruit samples				
	Avocado pear	Cashew apple	Sweet orange	Mango	Banana
Bleached palm oil	0.035 (87.5)	0.080 (60.6)	0.084 (25.3)	0.028 (31.8)	0.045 (52.3)
Sheabutter	0.026 (65.0)	ND	0.240 (72.3)	0.032 (36.4)	0.040 (46.5)
Vegetable oil	0.024 (60.0)	ND	0.040 (12.0)	0.040 (45.5)	0.044 (51.2)
Animal fat	0.024 (60.0)	ND	0.040 (12.0)	0.044 (50.0)	0.024 (46.5)
Unwaxed fruit	0.024 (60.0)	ND	0.120 (36.1)	0.084 (95.4)	0.024 (46.5)
Fresh fruit (not under storage	0.040	0.132	0.332	0.088	0.086

Values expressed as average of 3 determinations. Values in a parenthesis represent retained vitamin C (%); ND: Not determined

Table 2c: Brix level of waxed fruits stored at the ambient storage conditions for seven days

Coating agent	Ripened fruit samples				
	Avocado pear	Cashew apple	Sweet orange	Mango	Banana
Bleached palm oil	0.0	6.0 (0.12)	9.0 (0.08)	9.5 (0.10)	14 (0.06)
Sheabutter	0.0	ND	8.5 (0.11)	8.7 (0.07)	13 (0.13)
Vegetable oil	0.0	ND	8.0 (0.05)	7.5 (0.03)	13 (0.10)
Animal fat	0.0	ND	8.0 (0.02)	9.0 (0.05)	10 (0.01)
Unwaxed fruit	0.0	ND	9.5 (0.06)	10 (0.05)	13 (0.06)
Fresh fruit (not under storage	0.0	10.0 (0.01)	10.0 (0.05)	10.0 (0.03)	16(0.07)

Values represent average of 3 determinations (±SEM), ND: Not determined due to deterioration

Table 2d: Sensory assessment of ripened fruits coated with four different edible fats/oils and kept under ambient storage conditions for seven days

A. Ripened banana fruit preserved by waxing

Sensory attributes	Mean scores of banana fruit samples					
	A	B	C	D	E	F
Peel colour	2.0^{a}	3.4^{b}	3.1^{b}	3.0^{b}	3.2^{b}	4.4^{b}
Texture	2.0^{c}	2.4^{c}	3.2^{d}	3.2^{d}	2.3^{c}	3.9^{d}
Taste	2.1^{e}	3.6^{f}	3.0^{f}	2.8^{e}	2.4^{e}	4.6^{f}
Flavour	2.6^{g}	2.1^{g}	2.4^{a}	3.5^{h}	2.1^{g}	4.5^{h}
Acceptability	2.1^{i}	2.2^{i}	3.5^{l}	3.5^{l}	2.4^{c}	4.3^{l}

B. Sweet orange fruit preserved by waxing

Sensory attributes	Mean scores of sweet orange samples					
	A	B	C	D	E	F
Peel colour	3.0^{a}	3.0^{a}	3.3^{a}	3.0^{a}	4.1^{a}	4.3^{a}
Texture	4.1^{b}	4.3^{b}	3.0^{b}	4.2^{b}	3.1^{b}	3.8^{b}
Taste	4.2^{c}	4.5^{c}	4.2^{c}	4.4^{c}	3.1^{c}	4.6^{c}
Flavour	4.0^{d}	4.4^{d}	4.3^{d}	4.3^{d}	3.0^{e}	4.5^{d}
Acceptability	4.3^{g}	3.0^{f}	4.2^{g}	4.3^{g}	3.3^{f}	4.7^{g}

C. Ripened avocado pear preserved by waxing

Sensory attributes	Mean scores of avocado pear samples					
	A	B	C	D	E	F
Peel colour	2.4^{a}	2.6^{a}	3.5^{b}	2.1^{d}	2.3^{a}	3.7^{b}
Texture	3.4^{c}	3.4^{c}	3.6^{c}	3.5^{c}	3.1^{c}	3.5^{c}
Taste	3.1^{d}	3.0^{d}	3.4^{d}	3.2^{d}	2.7^{e}	4.7^{d}
Flavour	3.0^{e}	3.4^{e}	3.3^{e}	3.5^{e}	3.0^{e}	3.5^{e}
Acceptability	2.2^{f}	2.4^{f}	2.1^{f}	3.5^{g}	2.7^{f}	3.7^{g}

D. Ripened mango fruit preserved by waxing

Sensory attributes	Mean scores of mango samples					
	A	B	C	D	E	F
Peel colour	2.3^{a}	2.7^{b}	2.7^{b}	3.0^{c}	3.7^{b}	3.8^{b}

Texture	2.0^{c}	1.7^{c}	3.7^{d}	3.3^{d}	2.0^{c}	4.6^{d}
Taste	2.0^{f}	1.7^{f}	3.0^{e}	3.3^{a}	2.3^{f}	3.9^{e}
Flavour	2.8^{h}	3.0^{g}	3.2^{g}	2.6^{h}	1.8^{h}	3.7^{g}
Acceptability	2.6^{i}	2.0^{i}	3.7^{h}	3.2^{h}	2.4^{i}	4.0^{h}

E. Ripened cashew apple preserved by waxing

Sensory attributes	Mean scores of cashew apple samples					
	A	B	C	D	E	F
Peel colour	ND	ND	ND	ND	ND	-
Texture	ND	ND	ND	ND	ND	-
Taste	ND	ND	ND	ND	ND	-
Flavour	ND	ND	ND	ND	ND	-
Acceptability	ND	ND	ND	ND	ND	-

ND: Not determined due to deterioration. Means followed by the same superscripts in a row are not significantly different (P>0.05) Turkey's test. Sample codes: A : Unwaxed fruit (stored), B: Bleached palm oil wax, C: Sheabutter wax, D: Vegetable oil wax, E: Animal fat wax, F: Fresh fruit (control)

C. Modified Nitrogen Atmosphere Storage: This is applicable to ripened fruits only (both climacteric and non-climacteric). The principle involved:Under N_2 gas, there is no O_2 and therefore respiration rate remains constant (there is neither increase nor decrease in respiration). Biochemical activity at cellular level is stopped. Heat of respiration is not produced, no moisture loss and microbial growth is hindered coupled with fungicide treatment. The major source of N_2 is atmospheric air (78% of air is N_2), generated by removal of O_2 in the air through combustion method). In a study conducted on the effects of N_2 gas storageon shelf-life and qualities of ripened sweet orange, apple and tomato fruits (Orishagbemi and Sule, 2021; Orishagbemi and Shaba, 2015; Orishagbemi and Hussaini, 2011), Sweet orange, apples, tomatoes were stored for 45, 56 and 32 days respectively under nitrogen gas storage at the ambient conditions (27±2^{o}C; 75% RH), with retained natural nutrients and sensory attributes similar to the fresh commodities obtained from the market.

2.2 Processing of raw food commodities

Vice-Chancellor Ma, ladies and gentlemen, highlighted below are some of my research works on processing of indigenous food commodities to control postharvest losses and enhance value addition.

Processing simply means transforming raw food materials through a variety of unit operations, techniques or methods to other products (secondary or primary) against postharvest losses, wastage or deterioration to enhance safety, shelf-life extension, value addition, nutrification, convenience, aesthetics, adequate packaging and economic gains. Such food processing techniques include use of ambient and high temperatures, hot air drying or dehydration e.g. cabinet, foam-mat, solar, drum, kiln drying, blanching, pasteurization, sterilization, extrusion cooking, hot oil processing or frying, evaporation or distillation. Each technique is based on certain scientific principles and have specific application in the industries with peculiar advantages and demerits. I have used foam-mat drying extensively in my research as highlighted and described below including both basic and applied works. Foam-mat dehydration is one of the emerging techniques suitable for food preservation. It involves mixing of liquid or semi-liquid food material (not more than 35% solids) with a small amount of edible foam agent solution followed by whipping of the mixture (air incorporation) to produce a porous but stiff and stable product/foam mixture. The foam is then spread out in a mat or sheet in thin layer or strips and dried by heated air at atmospheric pressure and relatively low temperature. The product becomes porous, readily stable, attain low moisture content, retain original flavor, pigment and has excellent reconstitution property (Orishagbemi, 2011).

2.2a Foam-mat dehydration of ripe banana pulp

Assessment of the physicochemical properties and flavor profile of foam-mat dehydrated banana powder was carried out (Orishagbemi *et al*., 2010). Four banana cultivars (Bita hybrid BTA; Dwarf Cavendish DCB; Chinensis CHB and Giant Cavendish GCB) were obtained as soft-ripe fruits (18 – 25% Brix). Each fruit pulp was extracted, hydrolyzed by pectinase enzyme (at 40^{o}C), pulpy juice mixed with separate preparations of two foam agents (glyceryl monostearate (GMS), monoglyceryl palmitate (MGP) and GMS/MGP mixture (1:1) as 0.4% pulp and pulpy juice without foam agent. Each was then whipped (600 rpm, 6min) and dried (at 60- 70^{o}C) to obtain banana powder (500 µm particle size). Physico-chemical and flavor profile characterization ofeach powder were measured.

The porosity of banana powder samples ranged from 59.2% - 68.4%, packed bulk density (0.60 – 0.66 g/cm^3), hydration capacity (2.60 – 2.78 gwater/gpowder), peak viscosity 3240 BU, reconstitution index of 0.30 – 0.40 (Tables 3a, b and c).

Table 3a: Packed bulk density and porosity of foam-mat dehydrated banana powder

	Packed bulk density (g/cm^3)				Porosity (%)			
Cultivar	GMS	MGP	GMSMGP	Control (No foam agent)	GMS	MGP	GMSMGP	Control (No foam agent)
BTA	0.63±0.004	0.63±0.004	0.62±0.003	0.59±0.003	64.3±0.05	59.2±0.01	62.8±0.07	41.4±0.04
DCB	0.63±0.004	0.62±0.004	0.62±0.001	0.58±0.004	59.1±0.03	63.6±0.03	60.9±0.05	43.8±0.01
CHB	0.66±0.002	0.64±0.002	0.64±0.003	0.61±0.002	68.4±0.01	61.5±0.04	61.4±0.03	51.2±0.02
GCB	0.62±0.001	0.60±0.003	0.61±0.004	0.57±0.004	65.7±0.04	66.2±0.02	66.1±0.06	43.7±0.05

Values represent average of 3 determinations (±SD)
BTA = Bita Hybrid Banana

DCB = Dwarf Cavendish Banana
CHB = Chinensis Banana
GCB = Giant Cavendish Banana

Table 3b: Colour and hydration capacity of foam-mat dehydrated banana powder

Visual colour				Lovibond matching colour				Water holding capacity g water/g powder			
GMS	MGP	GMS/ MGP	Control	GMS R-red Y-yellow B – blue	MGP R Y B	GMS / MGP R Y B	Control R Y B	GMS	MGP	GMS/MGP	Control
LB	LB	LB	B	6.0	7.1	6.2	6.5	2.60 ±0.007	2.65±0.008	2.65±0.01	2.76±0.007
				8.0	6.9	8.1	8.4				
				7.1	7.3	6.9	7.1				
LB	LB	LB	B	6.1	6.0	5.9	6.1	2.62 ±0.006	2.70±0.007	2.68±0.008	2.74±0.006
				7.8	7.5	6.8	7.9				
				7.0	5.8	7.2	6.9				
PY	CY	CY	LB	4.2	4.0	4.1	6.1	2.63 ±0.01	2.68±0.009	2.63±0.009	2.75±0.008
				6.3	2.9	3.8	7.6				
				1.1	1.0	0.9	5.5				
CY	CY	CY	LB	5.1	4.0	4.3	5.3	2.59 ±0.009	2.66±0.01	2.65±0.008	2.78±0.007
				7.2	0.9	5.0	8.2				
				4.2	1.0	1.0	7.0				

Values represent means of 3 determinations (±SD). B = Brown; LB = Light brown; PY = Pale yellow; CY = Cream yellow; GMS: Glycerylmonostaerate; MGP: Monoglycerylpalmitate

Table 3c: Properties of reconstituted foam-mat dehydrated banana powder at ambient temperature (28±2^{o}C)

Cultivar	Reconstitution index/ratio (powder:water)			Visual colour				Lovibond matching colour				Texture			
	GMS	MGP	GMS/ MGP	GMS	MGP	GMS/ MGP	Control	GMS	MGP	GMS/ MGP	Control	GMS	MGP	GMS/MGP	Control
BTA	1:3.0	1:3.0	1:3.0	DW	DW	DW	CW	6.0	7.2	6.1	3.6	S	S	S	S
								7.9	5.9	7.8	0.9				
								6.9	6.6	6.5	1.1				
DCB	1:3.5	1:3.5	1:3.5	DW	LB	LB	CY	6.1	6.2	5.9	4.1	S	V	V	V
								7.8	7.1	6.4	2.9				
								7.0	6.6	6.9	1.0				
CHB	1:2.5	1:2.5	1:2.5	GY	PY	PY	CY	4.2	4.0	4.1	3.8	SV	V	V	V
								6.0	2.6	3.8	2.9				
								1.3	0.8	0.7	0.9				
GCB	1:3.0	1:3.0	1:3.0	GY	PY	PY	CY	5.2	4.1	4.0	4.2	S	V	V	V
								7.1	0.9	1.2	1.1				
								3.8	4.0	0.9	1.0				

DW – Dull white; CY – Cream yellow; LB – Light brown; GY – Golden yellow; CW – Cream white; PY – Pale yellow; S: Smooth paste; V: Viscous paste

The foamed samples were more porous (about 2 times) than non-foamed, regardless of banana cultivar. The porosity data revealed that BTA and CHB with GMS, DCB and GCB with MGP are more porous by about 3% than others. High porosity of sample was adduced to higher volume of trapped air and greater interstitial spaces obtained during whipping operation, especially hydrolyzed, foamed banana paste. Packed bulk density values of foam-mat dried banana samples were greater than the non-foamed, but not more than 5 – 7%. It was an indication of light particles of powder. Apparently, CHB (Chinensis banana) had the highest bulk density. The use of GMS and MGP contributed to high packed bulk density values of banana powder, suggesting high porosity as obtained for the samples. The results of statistical analysis (SEM) showed that banana cultivar had no effect on porosity and packed bulk density of banana powder.

GMS incorporated banana samples had lower hydration/swelling capacity (2.61±0.2 g water/g powder) than the corresponding MGP sample (2.68±0.3 g water/g powder), while unfoamed samples had highest value (2.76±0.2%) because the sample contained more banana dry matter content which could absorb water and swell. Conversely, foamed samples had lower values due to less dry banana content admixed with either GMS or MGP which could only swell slightly at 28±2°C. Greater hydration capacity of MGP containing samples compare to those with GMS, implied that MGP had the tendency to swell more than GMS no matter how little under hydration conditions. Invariably, variation of hydration capacity among the four cultivars for either GMS, MGP or control was quite negligible. Lower hydration capacity values of foamed sample indicated that they would be less hygroscopic.

The reconstitution index ranged from 0.4 – 0.3 with variation among cultivars but not among foam agents. It was found that variations in reconstitution index had no effect on the reconstitution time (under 30 secs) and texture of reconstituted banana paste. Variation occurred in the reconstituted banana paste due to cultivar effect rather than foaming agent. Both CHB and GCB powder samples had cream-yellow (4.1 red, 1.2 yellow and 0.9 blue hues) reconstituted paste similar to the control which might be due to low polyphenol contents in banana pulp. Desirable colour exhibited by samples of both CHB and GCB cultivars suggested that the two cultivars could be mixed to produce banana powder and either GMS or MGP could be suitable foam agent. The texture of reconstituted GMS and MGP incorporated powder for all the 4 cultivars used were smooth, less viscous paste which resembled the hydrolyzed pulpy paste, except BTA and DCB samples that were off-colour. Smooth texture was attributed to excellent water wettability property of foamed samples, even at room temperature. The texture was similar to foamed fluid while milk and tomato with GMS, found wettable in water to obtain reconstituted whole milk and tomato paste of desirable smoothness and viscosity (Oguntunde and Adeojo, 1992 and Sanni *et al.*, 1999).

Flavour profiles of banana powder are presented in Figure 1. Fresh samples of banana powder (GCB, CHB,DCB and BTA) with GMS had flavour values of 1.22, 1.21, 1.8 and 1.08 mg Acetates/100g powder respectively and the corresponding samples when incorporated with MGP foam agent had 1.20, 1.19, 1.13 and 1.06 mgAcetate/100g sample. There was reduction of 7.90% - 12.10% in flavour volatiles and retention of 87 – 91% when compared with values of fresh raw ripe banana. For comparison purpose, about 68 – 72% banana flavour was reported to be retained in drum dried Cavendish banana, CHB (Anon, 1998). This showed that foam-mat drying technique could perform better than drum drying in retaining volatile flavour substance in banana powder.

Generally, both Giant Cavendish banana (GCB) and Chinensis banana (CHB) cultivars with GMS foam agent produced powder of most desirable colour and flavour retention apart from other physical qualities and therefore suitable for banana powder-making.

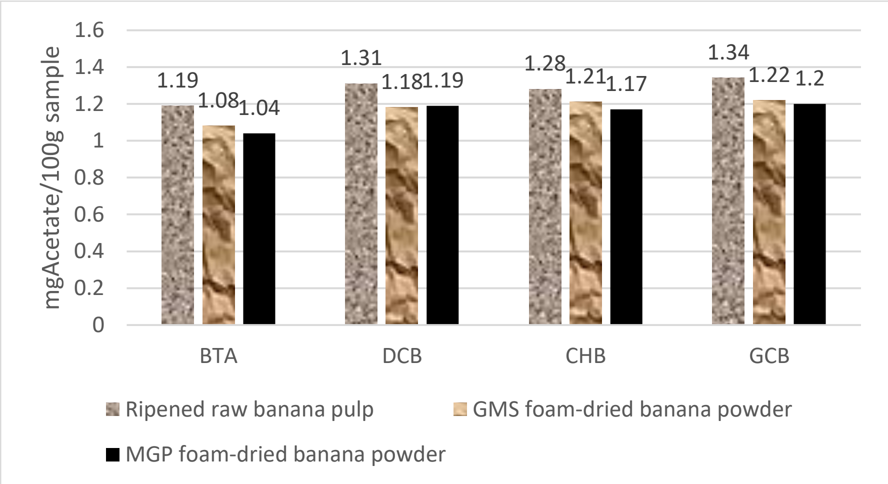

Figure 1: Flavour profiles of ripened banana pulp and foam-mat dried powder

In another study on toxicological evaluation of foam-mat dehydrated banana powder for food application (Orishagbemi *et al.*, 2015), we investigated the toxicological effects of banana powder in order to assess its safety for use as food ingredient.

Two banana cultivars, chinensis (PAR) and Giant Cavendish (SNR) at soft ripe stage were obtained and hydrolyzed pulp of each cultivar was prepared. A 2.5% suspension of glyceryl-monostearate (GMS) as edible foam agent was incorporated into the pastes at 0.4%, whipped, dried, milled (375 micron powder) and used for toxicological evaluation.

Fifty (50) male adult rats were fed extracts of banana samples at levels of 150, 250, 750 and 1000 mg/kg rat weight for 21 days. The rats' tissue/organs (liver, kidney, brain, heart, intestine) were also used for histopathological examinations. The serum protein ranged from 6.8 – 7.2 g/dL in rats administered PAR and SNR extracts. Albumin and globulin contents ranged from 4.1 – 4.5 and 2.5 to 3.9 g/dL respectively and blood glucose levels varied from 120 – 125 and 120 – 127 mg/dL respectively.

The serum alkaline phosphatase (ALP), alanine amino transferase (ALT) and aspartate amino transferase (AST) contents of rats ranged from 77 – 92, 26 – 39 and 38 – 45 µg/L respectively. The average packed cell volume (PCV) ranged from 43.5 – 47.0 % for rats fed PAR and SNR extracts, haemoglobin (Hb) (14.1 – 14.6 g/100ml) of the rats varied.

Rats administered SNR and PAR extracts (750 – 1000 mg/kg body weight) had liver that showed moderately congested hepatocellular sinusoids, no visible lesions, brain with normally congested vessels, heart with no myocardial degeneration similar to those of the control. The kidney showed moderatetubular epithelium, intestine with normal architecture, vicci and no visible lesions. The use of GMS as edible foam agent in banana powder was safe and constituted no health hazard to experimental rats (Tables 4a, b).

Table 4a: Biochemical parameters of blood serum of experimental rats (Orishagbemi *et al*., 2015)

Parameter	Sample	GP1	GP2	GP3	GP4	GP5
Protein (g/dL)	PAR	6.9±0.01^{e}	7.2±0.03^{e}	7.0±0.01^{e}	7.2±0.01^{e}	7.3±0.04^{e}
	SNR	7.4±0.02^{e}	7.1±0.01+e	6.9±0.04^{e}	6.8±0.02^{e}	6.8±0.01^{e}
Albumin (g/dL)	PAR	4.3±0.009^{f}	4.3±0.01^{f}	4.3±0.01^{f}	4.4±0.05^{f}	4.3±0.02^{f}
	SNR	4.4±0.05^{f}	4.4±0.03^{f}	4.5±0.06^{f}	4.1±0.001^{f}	4.0±0.03^{f}
Globulin (g/dL)	PAR	2.8±0.008^{g}	2.9±0007^{g}	3.0±0.01^{g}	2.8±0.009^{g}	3.0±0.007^{g}
	SNR	3.0±0.006^{g}	2.7±0.01^{g}	2.5±0.008^{g}	2.7±0.01^{g}	2.8±0.008^{g}
A.G ratio	PAR	1.5±0.003^{s}	1.5±0.009^{s}	1.4±0.01^{s}	1.6±0.007^{s}	1.6±0.005^{s}
	SNR	1.5±0.001^{s}	1.6±0.003^{s}	1.7±0.02^{s}	1.6±0.006^{s}	1.4±0.03^{s}
AST (µ/L)	PAR	42±0.14^{h}	43±0.21^{h}	40±0.20^{h}	44±0.22^{h}	43±0.18^{h}
	SNR	38±0.11^{i}	43±0.18^{h}	42±0.19^{h}	45±0.23^{h}	43±0.20^{h}
ALT (µ/L)	PAR	26±0.13^{i}	28±0.15^{i}	30±0.11^{i}	28±0.11^{i}	28±0.13^{i}
	SNR	26±0.11^{i}	29±0.13^{i}	27±0.13^{i}	29±0.16^{i}	28±0.11^{i}
ALP (µ/L)	PAR	92±0.21^{k}	77±0.19^{j}	77±0.20^{j}	86±0.11^{k}	82±0.13^{j}
	SNR	80±0.19^{j}	76±0.15^{j}	85±0.17^{k}	85±0.14^{k}	88±0.11^{k}

Creatine (mg/dL)	PAR	0.50 ± 0.003^{g}	0.35 ± 0.007^{h}	0.56 ± 0.005^{c}	0.60 ± 0.001^{g}	0.42 ± 0.03^{h}
	SNR	0.28 ± 0.001^{i}	0.40 ± 0.002^{h}	0.28 ± 0.003^{c}	0.45 ± 0.002^{h}	0.25 ± 0.003^{i}
Glucose (mg/dL)	PAR	120 ± 0.23^{n}	121 ± 0.21^{n}	123 ± 0.16^{n}	126 ± 0.21^{n}	118 ± 0.31^{n}
	SNR	120 ± 0.27^{n}	122 ± 0.18^{n}	122 ± 0.11^{n}	127 ± 0.18^{n}	120 ± 0.26^{n}
Rat weight increase (%)	PAR	15.1 ± 0.07^{a}	25.7 ± 0.1^{b}	15.8 ± 0.12^{a}	31.0 ± 0.07^{b}	10.1 ± 0.08^{c}
	SNR	28.0 ± 0.05^{a}	41.8 ± 0.08^{d}	24.4 ± 0.03^{b}	29.5 ± 0.11^{b}	8.7 ± 0.01^{c}

Values represent average of 5 measurements (±SEM)

Means in a row with the same letter are not significantly different ($P>0.05$)

GP1 : 150mg Banana extract/kg body weight

GP2 : 250mg Banana extract/kg body weight

GP3 : 750mg Banana extract/kg body weight

GP4 : 1000mg Banana extract/kg body weight

GP5 : 3mL Distilled water/rat (control)

PAR : Chinensis Banana Powder with GMS foam agent

SNR : Giant Cavendish banana powder with GMS foam agent

Table 4b: Complete blood count analysis of experimental rats blood serum

Parameter	Sample	GP1	GP2	GP3	GP4	GP5
PCV%	PAR	44.0±0.13[a]	43.5±0.11[a]	45.4±0.18[a]	47.0±0.22[a]	45.6±0.17[a]
	SNR	45.0±0.11[a]	46.0±0.15[a]	46.0±0.21[a]	45.0±0.19[a]	39.2±0.21[a]
Hb (g/mL)	PAR	14.1±0.16[b]	14.2±0.11[b]	14.6±0.13[b]	14.2±0.09[b]	14.5±0.11[b]
	SNR	14.3±0.13[b]	15.0±0.19[b]	14.5±0.19[b]	14.5±0.14[b]	12.4±017[b]
Rbc (×10^6μL)	PAR	7.3±0.001[c]	7.4±0.005[c]	7.7±0.01[c]	7.8±0.02[c]	7.6±0.01[c]
	SNR	7.3±0.003[c]	7.8±0.04[c]	7.8±0.003[e]	7.9±0.05[c]	6.5±0.01[c]
Wbc (×10μL)	PAR	8,380[d]	6,263[e]	8,620[d]	9,120[d]	9,790[d]
	SNR	7,238[d]	6,290[e]	9,612[d]	6,838[d]	87,700[d]
Platelet	PAR	119,600[f]	105,500[g]	137,200[f]	125,200[f]	129,800[f]
	SNR	116,500[f]	105,600[g]	121,800[f]	106,00[f]	120,000[f]
Lypm (%)	PAR	66.8±0.11[h]	70.3±0.19[h]	63.8±010[h]	68.0±0.13[h]	69.0±0.20[h]
	SNR	65.3±0.16[h]	53.0±0.11[h]	67.8±0.13[h]	69.5±0.10[h]	73.0±0.16[h]
Neuro (%)	PAR	28.6±0.11[i]	26.0±0.13[i]	32.0±0.15[i]	26.8±0.10[i]	26.8±0.14[i]
	SNR	31.0±0.10[i]	2.6±0.01[k]	27.8±0.13[q]	26.3±0.13[i]	23.0±0.11[i]
Mono (%)	PAR	2.0±0.02[i]	1.5±0.01[l]	1.2±0.07[m]	2.0±0.01[i]	2.4±0.01[k]
	SNR	2.0±0.01[i]	2.6±0.01[k]	1.8±0.05[l]	26.3±0.13[i]	1.5±0.02[m]
Eos	PAR	2.6±0.01[p]	1.8±0.04[n]	3.2±0.06[p]	2.4±0.01[p]	1.8±0.03[n]
	SNR	1.8±0.02[m]	1.6±0.01[n]	2.8±0.07[p]	2.2±0.03[q]	2.5±0.05[p]

Values represent average of 5 measurements (±SEM)
Means in a row with the same letter are not significantly different (P>0.05)
GP1 : 150mg Banana extract/kg body weight
GP2 : 250mg Banana extract/kg body weight
GP3 : 750mg Banana extract/kg body weight

GP4 : 1000mg Banana extract/kg body weight
GP5 : 3mL Distilled water/rat (control)
PAR : Chinensis Banana Powder with GMS foam agent
SNR : Giant Cavendish banana powder with GMS foam agent

2.2b Foam-mat dehydration of pineapple and cashew apple juices into powder

The use of foam-mat drying has been reported for juices to overcome associated difficulties facing ordinary hot air cabinet drying, spray, drum, freeze drying techniques such as flavour loss, colour degradation and high operating cost (Orishagbemi *et al*., 2016). This report focused on foam-mat dehydration effect on the physical properties, micronutrient contents and sensory characteristics of pineapple and cashew juice powder. Improved pineapple and Brazilian cashew varieties, soy protein isolate/liquid egg albumin (as foam agents) were obtained. The fruits were separately prepared into pulpy juice (30 – 35% solids). Two concentration levels (1.0%, 2.0% pulpy juice) of soy protein isolate and egg albumin as foam agents were used in each case, whipped in food mixer (10 mins) and control sample. Stable foam formed was dried (60^{o}C) in tray dryer, milled into powder (375 µ size), packed (HDPE) and used for physical, nutrient and sensory evaluation. The foam-mat dried pineapple and cashew juice powder with added soy protein isolate showed higher hydration capacity (2.0 – 7.4 ml/g powder) regardless of the concentration (1 – 2%), while control samples had the highest hydration values (7.4 – 8.5 ml/g powder). Bulk density decreased as foam agent level increased due to increase in volume during whipping. Pineapple powder has lower reconstitution ratio (1:4) than cashew powder (1:5), which was not affected by the foam agent. pH values of reconstituted cashew juice (4.4 – 4.7) were lower than those of pineapple (4.9 – 5.1). Ascorbic contents of 209 – 230 and 87 – 112 mg/100g powder of cashew and pineapple respectively were obtained. Betacarotene (vitamin A precursor) ranged from 0.05 – 0.34 mg/100g powder which did not experience any loss.

The taste and flavour of foam-mat dried cashew juice (2.0% soy protein isolate) and control were similar, pineapple (2.0% egg albumin, 1.0% soy protein) and the control had similar high mean flavour and taste score. Practically and technically, it was feasible to produce quality foam-mat dried cashew apple juice powder using soy protein isolate asegg white was found equally suitable for producing pineapple juice powder with desirable quality attributes (Tables 5a, b and c) (Orishagbemi *et al*., 2015).

Table 5a: Some physical properties of foam-mat dried pineapple and cashew apple juice powder

Physical property		Samples				
		NFJ	EWJ 1.0%	SPJ 1.0%	EWJ 2.0%	SPJ 2.0%
Water absorption capacity (mL/g)	PA	8.2±0.1	7.2±0.2	7.8±0.0	6.9±0.1	8.0±0.2
	CA	7.4±0.04	7.0±0.02	7.1±0.03	7.0±0.02	7.1±0.01
Bulk density (g/mL)	PA	0.42±0.1	0.37±0.3	0.38±0.3	0.34±0.3	0.35±0.3
	CA	0.45±0.03	0.40±0.01	0.40±0.01	0.30±0.02	0.43±0.01
Reconstitution ratio (powder: water)	PA	1:4	1:4	1:4	1:4	1:4
	CA	1:5	1:5	1:5	1:5	1:5
Wettability (s)	PA	59±0.25	53±0.10	55±0.30	44±0.04	48±0.20
	CA	44±0.02	40±0.00	40±0.00	39±0.01	40±0.00
pH value	PA	4.6±0.02	4.9±0.01	5.0±0.03	4.9±0.04	4.9±0.20
	CA	4.4±0.10	4.6±0.03	4.5±0.01	4.6±0.02	4.7±0.01

Values represent average of 3 determinations (±SD)

Sample codes

NFJ	–	Non foamed juice powder
EWJ 1.0%	-	Egg white foamed juice powder (1.0%)
SPJ 1.0%	-	Soy protein foamed juice powder (1.0%)
EWJ 2.0%	-	Egg white foamed juice powder (2.0%)
SPJ 2.0%	-	Soy protein foamed juice powder (2.0%)
PA	-	Pineapple
CA	-	Cashew apple

Table 5b: Moisture, vitamin and acid content of foam-mat dried pineapple and cashew powder

Analytical parameter		Samples				
		NFJ	EWJ 1.0%	SPJ 1.0%	EWJ 2.0%	SPJ 2.0%
Moisture (%db)	PA	71±0.6	131±0.01	13.0±0.01	13.0±0.02	13.0±0.00
	CA	88±0.5	15.0±0.0	12.5±0.02	13.0±0.01	13.1±0.03
Ascorbic acid (mg/100g)	PA	112.2±0.6	6.87±0.4	91.0±0.3	91.0±0.3	91.2±0.3
	CA	230.0±0.3	198.1±0.5	209.1±0.4	209.0±0.3	218.1±0.5
Beta carotene (mg/100g)	PA	0.018±0.01	0.052±0.0	0.06±0.00	0.054±0.00	0.050±0.00
	CA	0.34±0.01	0.31±0.02	0.22±0.05	0.25±0.05	0.19±0.05
Acid content as citric (mg/100g)	PA	13.3±0.1	12.4±0.3	16.1±0.03	16.4±0.01	8.6±0.01
	CA	9.6±0.00	9.7±0.01	9.5±0.01	9.6±0.05	9.3±0.05

Values represent average of 3 determinations (±SD)

Sample codes

NFJ – Non foamed juice powder
EWJ 1.0% - Egg white foamed juice powder (1.0%)
SPJ 1.0% - Soy protein foamed juice powder (1.0%)
EWJ 2.0% - Egg white foamed juice powder (2.0%)
SPJ 2.0% - Soy protein foamed juice powder (2..0%)
PA - Pineapple
CA - Cashew apple

Table 5c: Mean sensory scores of reconstituted cashew apple and pineapple juice powder

Sensory attribute		Samples				
		NFJ	EWJ 1.0%	SPJ 1.0%	EWJ 2.0%	SPJ 2.0%
Colour	PA	4.4^{b}	4.0^{b}	4.6^{b}	5.8^{a}	6.6^{a}
	CA	5.5^{b}	6.4^{a}	6.5^{a}	6.2^{a}	7.0^{a}
Taste	PA	5.5^{d}	4.8^{dc}	5.0^{d}	6.3^{c}	6.9^{c}
	CA	6.0^{b}	5.7^{c}	6.4^{b}	5.7^{c}	6.8^{b}
Flavour	PA	5.4^{f}	4.6^{ef}	5.0^{f}	6.3^{a}	6.7^{e}
	CA	5.6^{e}	5.9^{d}	6.2^{d}	5.6^{a}	7.0^{d}
Consistency	PA	6.1^{g}	4.6^{h}	5.0^{h}	6.3^{g}	6.7^{g}
	CA	5.3^{f}	4.8^{e}	6.0^{a}	5.0^{f}	6.6^{a}

Values represent average of 10 panelists. Means in a row with the same superscripts are not significantly different (p>0.05)

Sample codes

NFJ	–	Non foamed juice powder
EWJ 1.0%	-	Egg white foamed juice powder (1.0%)
SPJ 1.0%	-	Soy protein foamed juice powder (1.0%)
EWJ 2.0%	-	Egg white foamed juice powder (2.0%)
SPJ 2.0%	-	Soy protein foamed juice powder (2..0%)
PA	-	Pineapple
CA	-	Cashew apple

2.2c Production of mango powder for industrial utilization by foam-mat dehydration

Vice-Chancellor Ma, I won CERAD/FUTA research award (2007) titled "Dr. Ayo Ajayi Fellowship in Food Storage and Preservation" to conduct the above mentioned research which was successfully completed and final report submitted where, mango powder was used to produce two major products namely mango juice and ogi-mango powder as breakfast complementary food.

Nigeria is one of the world leading producers of mango fruits, with annual production volume of about 1,470,000 metric tons and unfortunately, 30 – 40% postharvest losses occur due to lack of storage facilities and little or no processing for its preservation. Appropriate processing of ripened mango fruits which is nutritious into value – added food and industrial ingredients would expand its utilization beyond domestic consumption, eliminate waste and generate wealth. The aim of the work was to produce and evaluate foam-mat dried mango powder and ogi-mango mix powder (a complementary/breakfast food).

Selected five mango cultivars, namely Cheri (CHE), Ankpa (ANK), Paparanda (PAP), Alphonso – Hybrid (ALP) and Kerosene (KER) at 8 – 10% Brix were obtained and analysed for physical and nutrients composition. Extracted mango pulp (fresh) of each cultivar and combination (four cultivars in equal proportion) were converted into smooth puree. Edible foam agents glycerylmonostearate (GMS) and monoglycerylpalmitate (MGP) as 0.25% mango puree were prepared into 5% suspension. The mango puree with foaming agent/carrier mixture were whipped (10^3 rpm) for 5 and 10 minutes, to determine foam capacity. Foamed mixtures were subsequently dried (60^{o}C), scrapped, milled (250 microns), packaged in 0.22 mm gauge high density polyethylene, sealed in chipboard box and stored (28±2°C) prior to analysis, production of powder mix (ogi-mango), sensory evaluation and storage studies. Fresh and stored samples of mango and ogi-mango powders reconstituted into puree/indirect mango juice and ogi-mango gruel were evaluated for physical, chemical/nutrient, microbiological, toxicological and sensory properties. Data were analysed using standard error of the means (SEM), ANOVA and means separated by Tukey's test.

Mango pulp content was high (56 – 80%), characterized by sweet taste (8 – 10% Brix), golden/cream yellow colour, intense flavour, high beta-carotene content (0.36 – 0.51 mg/100g), Vitamin C (39 – 50 mg/100g) and soluble solids (9 – 13%) which varied among cultivars. Foam volume increase with GMS was highest (42%) and least value (16%) with the control sample and did not vary much with whipping duration and among individual cultivars and combinations. Powders showed low packed bulk density (0.95 – 1.01 g/cm^3) and lower in foam-mat dried powder with GMS and MGP and ogi-mango. Hydration capacity ranged from 2.61 – 2.98 gwater/gsample (mango powder and ogi-mango). Reconstituted mango puree (mixed cultivars) had low peak viscosity value (1.50 RVU), compared to 21.83 and 61.42 RVU values for ogi-mango and pure ogi respectively. Reconstitution ratio of mango powder (1:3.5) did not vary among foam agent, while reconstitution time (20 – 45 seconds) was found to vary and had no effect on the texture of product. The colour of reconstituted puree (mixed cultivars) were Golden/Creamy yellow similar to the control while that of GMS incorporated sample had brilliant golden yellow colour. Mango powder yield (18.9 – 22.3%), moisture content (6.2±0.1% db), carbohydrates (79 – 82%), vitamin A (1.12 – 1.15 mg/100g), Fe (0.39 – 0.41 mg/100g), Energy (1.438

kj/kg). Ogi-mango has higher values of protein (9.62%), Energy (1.540 kj/kg), Fe (0.60 mg/100g) (Table 6a, b and c). Total aerobic counts (18 – 26 cfu/g mango powder, 98 – 100 cfu/g ogi-mango), coliform (0.00 cfu/g for both powders). Generally, GMS foam agent was found most suitable and powder from CHE, ANK, PAP, ALP cultivars, and mango powder and ogi-mango blend revealed a shelf-life of 12 and 15 months respectively at 28±2^{o}C with retention of sensory properties.

Four among five cultivars, Cheri (CHE), Ankpa (ANK), Paparanda (PAP) and Alphonso (ALP) and their combination(s) with glycerylmonostearate (GMS) as foaming agent, are suitable for producing powders having excellent reconstitution properties, sensory attributes and acceptability.

Table 6a: Chemical/Nutrients composition of mango powder and ogi-mango blend (Orishagbemi, 2009)

Sample	% Moisture (db)	% Carbohydrates	% Protein (N×6.25	% Fat	% Acidity (citric)	Vitamin C (mg/100g)	B-carotene (mg/100g)	Potassium (mg/100g)	Iron (mg100g)	Energy value (KJ/100g)	Magnesium (mg/100g)
MIX GMS	6.20^{a}	79.20^{c}	2.58^{a}	3.40^{b}	2.65^{b}	70.00^{a}	1.15^{a}	70.00^{c}	0.40^{j}	$1,438^{a}$	5.80^{f}
MGP	6.20^{a}	78.91^{d}	2.58^{a}	3.38^{b}	2.68^{b}	69.04^{a}	1.14^{a}	68.37^{c}	0.45^{j}	1.438^{a}	5.69^{f}
STA	6.05^{b}	82.11^{b}	2.56^{a}	3.38^{b}	2.62^{b}	66.88^{a}	1.15^{a}	71.04^{c}	0.39^{j}	$1,461^{a}$	5.78^{f}
Control	6.20^{a}	80.05^{c}	2.55^{a}	2.71^{c}	2.65^{b}	57.15^{b}	1.12^{a}	70.60^{c}	0.41^{j}	$1,401^{a}$	5.82^{f}
Ogi-Mango blend	6.05^{b}	74.81^{e}	9.62^{b}	5.12^{a}	2.77^{b}	48.02^{b}	0.94^{a}	51.20^{d}	0.60^{j}	$1,540^{b}$	5.80^{f}
Ogi-powder	6.05^{b}	85.13^{a}	3.87^{a}	1.89^{d}	2.91^{a}	25.0^{c}	0.33^{b}	31.22^{e}	0.78^{k}	$1,613^{b}$	4.22^{e}

Values represent mean of 3 determinations. Means in a column with the same letter are not significantly different ($p>0.05$)

MIX – Mixture of CHE, ANK, PAP and ALP mango cultivars

Table 6b: Means sensory scores of mango powder stored for 12 months (at 28±2ºC)

Sensory attributes	GMS	MGP	STA	CTR
Visual colour	6.92^{a}	6.66^{a}	5.85^{a}	7.00^{a}
Flavour	6.62^{b}	6.58^{b}	5.11^{c}	6.93^{b}
Taste	6.83^{d}	6.67^{d}	5.96^{d}	6.96^{d}
Mouthfeel	6.54^{e}	6.11^{e}	5.30^{e}	7.00^{e}
Acceptability	6.55^{f}	6.42^{f}	5.32^{g}	6.94^{f}

Mean followed by the same superscript letters along the same row, are not significantly different (p>0.05, Tukey's test)

Table 6c: Means sensory scores of fresh ogi-mango mix reconstituted and prepared into gruel food.

Sensory attributes	1	2	3	4	Control
Visual colour	4.22^{a}	5.61^{a}	6.47^{a}	6.93^{a}	3.53^{b}
Taste (sweetness)	5.25^{b}	5.88^{b}	6.97^{c}	7.00^{d}	4.04^{e}
Flavour/aroma	4.71^{f}	6.01^{f}	6.95^{f}	6.89^{f}	2.85^{g}
Consistency/texture	6.61^{h}	6.96^{h}	6.54^{h}	6.92^{h}	6.96^{h}

Mean followed by the same superscript letters along the same row, are not significantly different (p>0.05, Tukey's test)

2.2d Foam-mat dehydration of whole liquid egg (Orishagbemi *et al*., 2017)

This study was carried out to produce and characterize the physical and functional properties of foam-mat dried whole egg powder (local hens and poultry layer's eggs) for standardization purpose and also evaluated the sensory attributes to ascertain suitability for different food applications (dehydration of egg by spray and drum drying has been shown to be associated with high energy input costs and is not technologically feasible for commercialization as such foam-mat drying is a suitable alternative drying option since it is cheap to run, operate and environment friendly).

Both fresh local and poultry eggs (LE and PE respectively) were obtained, then separately prepared into whole liquid egg of stable foam by whipping (egg white served as natural foam agent) and dried (60^{o}C) in tray dryer, then milled into powder (180 µ particle size), packaged and kept under refrigeration until used for physical, functional property and sensory evaluation using standard methods. The foaming capacity of liquid egg (LE and PE) ranged from 20.10% - 20.5% and corresponding egg powder, 17.0% - 18.2%. Slight reduction in foaming capacity of dried powder was attributed to heat effect on the egg albumin. Egg powder bulk density (0.45 – 0.62 g/ml), local egg powder with greater value, due to bulkier egg yolk content. Water absorption capacity (7.8 – 8.0 ml/g powder), where poultry egg showed higher value, did not seem to affect its reconstitution. The colour of reconstituted boiled local egg powder was rated higher (6.10), so also texture (6.71), flavour (6.04), taste (6.57) and mouthfeel (6.45) of boiled poultry egg. Reconstituted fried poultry egg powder (omelet) has higher texture, colour, flavour, mouthfeel scores and lower taste than local egg powder. Apparently, poultry egg powder was found to be more suitable than local egg as potential industrial ingredientfor various food applications (baked products, cookies/snacks, baby foods, ice-cream) based on desirable physical, functional and sensory attributes (Tables 7a, b and c).

Table 7a: Some physical, functional properties and moisture content of foam-mat dried whole egg powder

Physical/functional property	Sample LE	Sample PE
Foaming capacity (%)		
Before drying	20.1±0.02	20.5±0.02
After drying	17±0.01	18.2±0.01
Bulk density (g/mL)	0.62±0.01	0.45±0.02
Water absorption capacity (mL/g)	7.8±0.02	8.0±0.02
Reconstitution ratio (powder: water)	1:3	1:3
Wettability (s)	8.2±0.02	7.5±0.03
Gelation capacity (%)	6.0±0.11	5.0±0.08
Emulsification capacity (%)	44.8±0.15	32.0±0.11
Moisture (%)	5.1±0.01	4.8±0.02

Values represent average of 3 determinations ±SEM. Sample codes: LE (eggs from local hens), PE (eggs from poultry hens) and SEM (standard error of the mean)

Table 7b: Mean sensory scores of reconstituted boiled whole egg powder and the control (boiled whole liquid egg)

Sensory Attribute	Sample			
	LEP	LEL	PEP	PEL
Colour	6.10^{a}±0.13	6.00^{a}±0.11	5.86^{a}±0.11	6.35^{a}±0.21
Texture	6.40^{a}±0.09	6.55^{a}±0.22	6.71^{b}±0.82	6.85^{b}±0.15
Flavour	6.55^{a}±0.16	6.85^{c}±0.09	6.64^{c}±0.63	6.77^{c}±0.32
Taste	6.15^{a}±0.11	6.45^{d}±0.18	6.57^{d}±0.64	6.42^{d}±0.18
Mouthfeel	6.20^{a}±0.30	6.67^{e}±0.20	6.45^{e}±0.22	6.38^{e}±0.20

Values represent average of 10 determinations ±SEM. Means in a row with the superscripts are not significantly different ($p>0.05$).

Sample codes: LEP = Local egg powder, PEP = Poultry egg powder; LEL = Local egg liquid; PEL = Poultry egg liquid (control)

Table 7c: Mean sensory scores of reconstituted fried whole egg powder and the control (fried whole liquid egg)

Sensory Attribute	Sample			
	LEP	LEL	PEP	PEL
Colour	5.95^{b}±0.21	6.50^{b}±0.10	6.25^{a}±0.08	6.85^{b}±0.10
Texture	6.30^{a}±0.15	6.72^{a}±0.11	6.38^{a}±0.20	6.90^{a}±0.18
Flavour	5.95^{c}±0.09	6.38^{c}±0.12	6.05^{c}±0.32	6.45^{c}±0.26
Taste	6.90^{d}±0.01	6.85^{d}±0.08	5.88^{d}±0.11	6.05^{d}±0.20
Mouthfeel	5.85^{3}±0.10	6.35^{e}±0.08	6.40^{e}±0.06	6.50^{e}±0.02

Values represent average of 10 determinations ±SEM. Means in a row with the superscripts are not significantly different ($p>0.05$).

Sample codes: LEP = Local egg powder, PEP = Poultry egg powder; LEL = Local egg liquid; PEL = Poultry egg liquid (control)

3.0 Food product development research works

The Vice-Chancellor Ma, I still want to mention some new products developed by me, under food product development research. Food product development simply means laboratory and industrial researches directed at developing or evolving food product and process to satisfy a known or suspected consumer need(s). It involves series of methods for selecting, evaluating and developing new products for specific consumer or user needs. Also, it concerns search for completely new product or the modification and improvement of an existing food product. The activities of food product development include product idea conception, development (formulation and process), evaluation, improvement and suitability for the market. It requires creativity and innovation which start with ideas, requires combined efforts of an interdisciplinary team (R&D scientists, marketing research, quality control, assurance, engineering, sales, purchasing, consulting, advert and packaging experts). It is time consuming and expensive to conduct.

3.1 Production and quality evaluation of imitation/analogue egg powder(Orishagbemi *et al.*, 2017)

This is one of the typical examples of my research on food product development. Natural edible egg is an animal – based product, laid by birds such as hen, duck, turkey, quail and composed of egg white or albumin (about 62%) and yolk (38%). A typical egg has balanced food nutrients, containing proteins (13.78%), fat (12.49%) carbohydrates (14.25%), vitamins (6.35%), ash as minerals (2.84%) and water (50.29%). It is a rich source of complete amino acids (Aduku and Olukosi, 2000). The presence of cholesterol and anti-nutrients (such as avidin and allergins) in eggs limits its nutritional benefits. For instance, avidin has been shown to inhibit biotin vitamin absorption, which is necessary for fatty acid synthesis and blood sugar regulation, and neither frying nor boiling can destroy it completely (Norman and Joseph, 2006). Again, it has been reported that some people show allergic reaction to egg consumption. According to reportsby Yeshayahu(1999), eggs have been shown to serve various functions in food as binder, thickener, agent for coating, foaming, leavening and emulsification, nutrient fortifier and colourant due to the presence of the albumin and yolk components that confer such functional properties on whole egg. In recent times, it has been reported that the quantity of eggs produced in most countries is insufficient to meet the requirement of the populations, especially African states and sub-region. Intensified research into the development of egg substitute products to mimic natural, using natural raw materials is worthwhile. Such imitation or analogue egg products would be cholesterol and anti-nutrient free, constitutes no allergin, able to furnish or supply balanced nutrients, possess functional properties similar to egg, and be made available in substantial quantities to meet world consumer requirements when combined with insufficient production output. Therefore, the main purpose of this work was to produce and evaluate the functional properties, sensory attributes and nutrients composition of egg substitute powder products using natural raw materials such as soybeans (36.4% proteins), cowpea (22.7% protein), wheat glutein (100% protein), yellow fleshed potato (20.1% carbohydrates), trifoliate yam (37.4% carbohydrates), melon (7% protein, 14.5% fat), taste enhancer (table salt), egg flavour, antioxidant and preservative.Five different samples of imitation egg powder were produced from natural raw materials (Soybean, white cowpea, wheat glutein, melon, yellow sweet potato and trifoliate yam, each converted into flour) obtained from Anyigba, Nigeria. They were coded samples 101, 201, 301, 401 and 501 containing cowpea and soy content in ratios 1:1, 2:1, 1:2, 3:2 and 2:3 respectively, while the proportion of other ingredients remained the same in each sample. Commercial whole egg powder (sample 601) was provided as the control. Each sample was packaged in HDPE bag, kept under refrigeration not longer than 4 weeks for functional property, sensory evaluation, nutrients composition and statistical data analysis using standard methods.

A. Physical and functional properties of imitation egg powder samples

The bulk density, foaming capacity, wettability, water hydration, oil absorption, emulsification and gelation capacities of imitation egg powder (egg substitute powder) samples and control (whole egg powder) are shown in Table 8. The bulk density values for the five experimental imitation egg powder ranged from 0.40 – 0.45g/ml, samples 301 and 201 showing the lowest and greatest values respectively, while sample 601 (control, whole egg powder) was 0.51 g/ml, greater than any of the imitation egg samples but not significantly different (p>.05). Greater bulk density of natural whole egg powder than the imitation egg powder was an indication of bulkier particle which might be due to the egg yolk content which is animal based. Foaming capacity also ranged from 30.0 – 41.0%, samples 401 and 201 with the lowest and highest values respectively, and the control (sample 601) with the value of 40.0% in between the experimental sample values. This showed that, there was equivalent egg albumin ingredient in the egg substitute (soy protein) since it was the egg white (albumin) that was responsible for the foam formation. This corroborate the fact that soy protein isolate has been shown to be a suitable foaming agent (Thuwanami*et al*., 2008). Wettability ranged from 6.10 -7.17s, including that of the control, which is 6.20s. All the samples showed low wettability values, which indicated good reconstitution property, similar to previous research findings on the physical and chemical properties of food powder (Barbosa–Canovas and Juliano, 2001). The samples had water absorption capacities ranging from 1.40 -1.80 (ml/g), samples 101, 201 and 601 (control sample) with 1.80, 1.60 and 1.60 ml/g respectively, and were not significantly different (p>0.05) while others had slightly reduced values, which however did not affect the reconstitution property. Oil absorption capacities of the sample were found to be similar, which ranged from 2.20-2.60 ml/g. The values represented allowable range for egg powder and related products. The samples had emulsification capacities that ranged from 44.0-44.8%, showing no significant difference (p>0.05) among the egg substitutes and whole egg powder (control). The 44.8% value for control was the highest, probably due to the natural egg white present which makes whole egg a good emulsifying agent. Also, gelation capacity values had a range of 5.0-6.5%, showing no significant difference (p>0.05) among the samples and even the control. Similarity in gelation property was explained as the result of preponderant protein quality and quantity in the samples.

Table 8: Physical and functional properties of egg substitute and control sample (whole egg powder)

Physical/functional properties	Sample					
	101	201	301	401	501	601
Bulk density (g/mL)	[illegible]^{a}±0.02	0.45^{a}±0.01	0.35^{a}±0.04	0.40^{a}±0.03	0.40^{a}±003	0.51^{a}±0.01
Foaming capacity (%)	40.2^{f}±0.04	41.0^{f}±0.02	35.0^{f}±0.05	30.0^{g}±0.04	32.0^{g}±0.03	40.0^{f}±0.02
Wettability (sec)	7.17^{b}±0.01	6.30^{b}±0.02	6.50^{b}±0.02	6.10^{b}±0.03	6.10^{b}±0.03	6.20^{b}±0.04
Water hydration capacity (mL/g)	1.80^{c}±0.02	1.60^{c}±0.01	1.40^{d}±0.02	1.40^{d}±0.01	1.45^{d}±0.01	1.60^{c}±0.02
Oil absorption capacity (mL/g)	2.60^{c}±0.02	2.20^{e}±0.01	2.20^{e}±0.02	2.25^{e}±0.01	2.20^{e}±0.03	2.60^{e}±0.03
Emulsification capacity (%)	44.0^{h}±0.01	44.5^{h}±0.02	44.0^{h}±0.03	44.0^{h}±0.02	44.5^{h}±0.01	44.8^{h}±0.02
Gelation capacity (%)	6.0^{i}±0.10	5.5^{i}±0.02	5.0^{i}±0.01	5.0^{i}±0.01	5.5^{i}±0.02	6.5^{i}±0.01

Reconstitution ratio: 3mL water/g powder. Values represent mean of 3 determinations ±SEM Means in a row with the same superscript letter are not significantly different (P>0.05)

SEM – Standard error of the mean

Sample codes:

Sample: 101 – Contains cowpea (1 part), soy (1 part)
201 – Contains cowpea (2 parts), soy (1 part)
301 – Contains cowpea (1 part), soy (2 parts)
401 – Contains cowpea (3 parts), soy (2 parts)
501 – Contains cowpea (2 parts), soy (3 parts)
601 – Whole egg powder (as control)

B. Organoleptic/sensory properties of egg substitute and whole egg powder samples

Table 9 shows the mean sensory scores of reconstituted fried egg substitute powder and whole egg powder (as control). The mean colour scores ranged from 4.64 -5.92; samples 101, 201, and 601 (control) with similar ratings of 5.92, 5.71 and 5.46 respectively. Samples 301, 401 and 501 were also similar in colour ratings but were found significantly different ($p \leq 0.05$)from the previous other samples probably due to caramelization reaction of sugar in the ingredients rather than normal maillard reaction that resulted into attractive brownish – yellow colour. Samples 101, 201, 301, 501 and 601 (control) had similar flavour scores ranging from 5.41-6.04 and sample 401 with mean score of 4.95 which was significantly different ($P \leq 0.05$) from others, indicating the absence of egg flavour, dominated by cowpea flavour. The texture rating for the samples were similar; ranging from 5.33-5.71, except sample 501 with lower rating of 4.88. This might be attributed to very high proportion of soy flour in the sample, that could contribute toughness. The taste scores for samples 101, 201, 301, 501 and 601 (control) were similar and ranged from 5.20-5.78, while sample 401 with mean taste score of 4.98 was slightly different. Apparently both flavour and taste followed the same trend among the samples. The mouthfeel scores for all the samples, including the control were similar and ranged from 5.10-5.64, showing no significant difference (p>0.05) among the egg substitute powder samples.

Table 9: Mean sensory scores of reconstituted fried egg substitute and control

Sensory attributes	Sample					
	101	201	301	401	501	601
Colour	$5.92^a±0.74$	$5.71^a±1.20$	$4.85^b±0.94$	$4.64^b±0.74$	$4.92^b±0.82$	$5.46^a±1.10$
Flavour	$5.64^e±0.74$	$5.41^c±1.05$	$5.54^c±0.86$	$4.95^d±0.77$	$5.48^c±0.90$	$6.04^c±0.63$
Texture	$5.64^f±0.49$	$5.40^f±1.01$	$5.37^f±1.44$	$5.33^f±1.10$	$4.88^g±1.05$	$5.71^f±0.82$
Taste	$5.78^h±0.84$	$5.55^h±0.84$	$5.48^h±1.25$	$4.98^h±1.03$	$5.20^i±0.95$	$5.57^h±0.64$
Mouth-feel	$5.22^k±0.52$	$5.03^k±0.33$	$5.52^k±0.65$	$5.45^k±0.51$	$5.10^k±0.83$	$5.64^k±0.60$

Values represent mean of 10 scores ±SEM (standard error of the mean)
Means in a row with the same superscript are not significantly different(P>0.05)
SEM – Standard error of the mean
Sample codes:
Sample: 101 – Contains cowpea (1 part), soy (1 part)
201 – Contains cowpea (2 parts), soy (1 part)
301 – Contains cowpea (1 part), soy (2 parts)
401 – Contains cowpea (3 parts), soy (2 parts)
501 – Contains cowpea (2 parts), soy (3 parts)
601 – Whole egg powder (as control)

C. Nutrient contents of egg substitute powder products and whole egg powder

Shown in Table 10 are the values of the moisture content, crude protein, ash, crude fibre, fat, carbohydrates and beta-carotene contents of the formulated egg substitute samples and whole egg powder. Moisture content (dry basis) ranged from

6.65 -6.8%, showing similarity and no significant difference (P>0.05) detected. The values were low enough with corresponding low water activity to guarantee safe keeping with extended shelf life, when packaged in moisture and gas proof container. Crude protein contents of samples ranged from 31.72 -43.15%, samples 201 and 501 with the lowest and highest values respectively. Both 401 and 501 samples had higher protein contents than whole egg powder (control sample) due to high proportion of cowpea and soy flour. Ash contents (as mineral elements) ranged from 2.25% (in sample 201) to 4.15% (in sample 401), control sample with 4.03%, and only sample 201 was significantly different in protein content due to its ingredient components. Again, all the experimental samples had crude fibre content, ranging from 0.61 – 1.50% due to the presence of fibrous ingredients and little or no fibre in whole egg powder (0.01%). However, the presence of small quantity of fibre in egg substitute would contribute some nutritional benefits. Crude fat ranged from 12.01% (sample 101) to 16.40% (sample 401) in experimental egg substitute samples and 10.94% in sample 601 (control) which was slightly lower, but did not constitute any significant difference. Higher fat contents might be contributed by melon ingredient, which could not constitute any source of cholesterol in imitation egg product. Total carbohydrates contents ranged from 35.3% (sample 301) to 38.52% (sample 101) and sample 601, (control) with 38.09%. No significant difference (p>0.05)was detected. Beta-carotene contents were found to range from 163.5 mg/100g (control sample 601) to 193.1 mg/100g (sample 301). All the experimental samples had higher beta carotene than the control (whole egg powder), which is nutritionally advantageous.

Table 10: Proximate and nutrient composition of egg

Values represent average of 3determinations ±SEM (standard error of the mean)

Means in a row with the same superscript are not significantly different(P≥0.05)

SEM – Standard error of the mean

Sample codes:

Sample: 101 – Contains cowpea (1 part), soy (1 part)
201 – Contains cowpea (2 parts), soy (1 part)
301 – Contains cowpea (1 part), soy (2 parts)
401 – Contains cowpea (3 parts), soy (2 parts)
501 – Contains cowpea (2 parts), soy (3 parts)
601 – Whole egg powder (as control)

Finally, it was found that samples 101 containing cowpea (1 part), soy flour (1 part) and 201, containing cowpea (2), soy flour (1) shared similar properties of bulk density, foaming, hydration, oil absorption, emulsification, gelation capacities and wettability with the whole egg powder (control). Colour, flavour, texture and taste sensory attributes were also similar to reconstituted fried whole egg powder. However, sample 101 was higher in crude fibre, fat, beta carotene and carbohydrates contents than sample 601 (whole egg powder as control). Samples 301, 401 and 501 were higher in crude protein and beta-carotene contents than sample 601 (control), but were less preferred in terms of colour and flavour sensory attributes. By and large, sample 101 shared the most similar functional, sensory and nutrient content properties with whole egg powder (sample 601) and showed to be the most appropriate egg substitute that resembled whole egg powder and thus, equally suitable as potential industrial ingredient for various food applications.

3.2 Production, quality and safety evaluation of strategic dietary protein juice products suitable for school children (Another product developed through my research effort)

Fruits and vegetables are rich natural sources of carbohydrates (soluble sugars), dietary fibre and vitamins (A, B, C, Folic), legumes/nuts good and cheap sources of vegetable protein/fat macronutrient minerals such as Potassium, Calcium, Magnesium, Iron, Zinc (Orishagbemi 2016, Duckworth, 2006). These legumes, nuts, fruits and vegetables can be processed into primary products such as vegetable milk, fruit juices, pure, concentrate, which can be admixed into a single product to furnish essential food nutrients (protein, natural sugars, fibre, fat, vitamins, and minerals). Such mixture of vegetable/animal milk liquid and fruit/vegetable juices is known as protein juice or drink. If only one fruit/vegetable juice is mixed with milk, it is known as "fruit shake", such as banana, guava, pineapple, citrus shake (IFT, 2006). A typical protein juice or drink has been shown to be richer in food nutrients than ordinary milk and fruit juice when considered individually, and hence protein drink is suitable as functional product for school age children (3 – 10 years) especially for nutrition intervention programme. Ordinary milk whether vegetable or animal-based is richer in protein and low in vitamins (for example, liquid soymilk has protein (4.15%), vitamins A & C (0.26 and 0.06mg/100g respectively. In Nigeria, available records showed that majority of school age children (3 – 10 years) both in public and private schools who suffered malnutrition, especially deficiency syndromes of protein and essential micronutrients (vitamins A, B, C, Folic) and minerals (Fe, Ca, Mg, K, Zn, I_2) manifested as kwashiorkor, anaemia, scurvy, night blindness (WHO, 2009). Therefore, the objective of this work was to evaluate qualities of strategic protein juice samples produced, suitable for feeding school children, (using citrus, cashew apple, watermelon, tomatoes, carrots and liquid soymilk) in terms of the sensory properties, nutrient contents and microbiological safety analysis.

Dietary Protein drink samples suitable for school children were formulated, produced and evaluated. Raw materials included cashew, sweet orange, watermelon, carrot, tomato juices (rich in natural sugars and vitamins) and liquid soymilk (rich in protein and minerals). Seven (7) mixed juices, each contained combination of two fruit/vegetable juices were blended with liquid soymilk separately at five different ratios of % mixed juice ratio and % soymilk (67:33,60:40, 50:50, 40:60 and 33:67), including control sample (exotic protein drink). All the experimental samples were subjected to sensory evaluation (colour, taste, flavour, mouth feel, consistency) and seven most promising samples, subsequently underwent chemical, microbiological and statistical data analyses.

Sensory attributes of dietary protein drink samples

Table 11 (a – g) highlighted the sensory attributes of dietary protein drink samples

Taste: Sample of mixed cashew + tomato/soymilk (60%/40% ratio respectively) was rated highest (6.9 - score), followed by mixed cashew + carrot/soymilk (50/50); watermelon + tomato/soymilk (50/50), orange + tomato/soymilk (55/45) and the least being mixed tomato + carrot/soymilk (50/50). Apparently, taste of all experimental samples were preferable to the control, and there was no significant different ($p \leq 0.05$) among samples. The superior taste of cashew + tomato and soymilk mixed drink is due to very high reducing/soluble sugars content. It was rated highest among other samples as revealed by chemical analysis, and similar to research report of direct relationship between taste/sweetness and sugar content of food drinks/juices.

Colour: Tomato + carrot/soymilk (50%/50%) sample had the highest score (7.00 mean) with bright pink colour, followed by watermelon + carrot/soymilk (50%/50%) with light pink colour, orange + carrot/soymilk (60%/40%) pale pink, cashew + carrot/soymilk (50%/50%), while orange + tomato/soymilk (55%/45%) was the least desirable with pale brown colour. There seemed to be significant difference ($p \leq 0.05$) in colour among the samples. Colour is attributed to natural pigment of component juices, which depended on the dominant type, carrot (pinkish yellow), tomato (purple-red), watermelon (pinkish red), soymilk (dull white).

Flavour: The cashew + carrot, watermelon + tomato, cashew + tomato-based protein drinks had superior flavour (mean score range, 6.5 – 7.00) over orange + tomato, watermelon + carrot-based samples. However, all the experimental protein drink samples had flavour preferred to the control with least mean score (5.80). Variation in flavour of samples was majorly as result of various volatile aromatic compounds present which was characteristic of each fruit/vegetable commodity and also, extent or degree of ripeness of such fruit.

Mouthfeel: The experimental protein drink samples showed similar mouthfeel, regardless of the mixture components. The mouthfeel mean scores ranged from 5.8 (tomato + carrot/soymilk, 50%/50%) to 6.7 (cashew + tomato/soymilk, 60%/40%) without any detectable significant difference ($p \geq 0.05$).

Consistency: It also followed similar trend as mouthfeel as mean score ranged from 6.5 – 6.9. Similarity was attributed to the similar granularity of samples, with slight variation in viscosity as reported in a previous work by the researchers (Orishagbemi *etal*., 2015). Based on the sensory attributes of experimental samples, especially taste and colour, seven samples with codes, AAA (mixed cashew + tomato/soymilk, 60%/40%), BBB (mixed cashew + carrot/soymilk, 50%/50%), CCC watermelon (mixed + tomato/soymilk, 50%/50%), DDD (watermelon and carrot/soymilk, 50%/50%), (orange EEE + tomato/soymilk,55%/45%), FFF carrot/soymilk, (orange 60%/40%) + and GGG (tomato + carrot/soymilk, 50%/50%) were promising desirable protein drinks and they were selected for chemical analysis, since protein, vitamin and mineral contents are other vital quality attributes required of typical protein drink for school children.

Table 11a: Mean sensory scores of protein drink from blends of watermelon/carrot mixed juice/soymilk Sample

Sample	Sensory attributes				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	5.44 ± 0.11^{ef}	5.73 ± 0.01^{c}	5.73 ± 0.12^{d}	5.83 ± 0.10^{b}	6.50 ± 0.03^{a}
60:40	5.57 ± 0.08^{e}	5.80 ± 0.10^{c}	5.81 ± 0.05^{d}	6.35 ± 0.06^{a}	6.50 ± 0.10^{a}
50:50	5.89 ± 0.01^{e}	5.67 ± 0.03^{c}	5.66 ± 0.03^{d}	6.60 ± 0.04^{a}	6.61 ± 0.02^{a}
40:60	5.70 ± 0.10^{ef}	5.56 ± 0.11^{c}	5.54 ± 0.10^{d}	5.84 ± 0.01^{b}	5.85 ± 0.01^{ab}
33:67	5.45 ± 0.00^{ef}	5.60 ± 0.05^{c}	5.65 ± 0.02^{d}	5.80 ± 0.01^{b}	5.671 ± 0.04^{ab}
CTL (control)	5.41 ± 0.02^{ef}	5.58 ± 0.00^{c}	5.79 ± 0.01^{d}	5.39 ± 0.02^{b}	4.56 ± 0.10^{b}

Values represent mean scores of 15 panelists ± SD (standard deviation). Values in a column with the same superscript are not significantly different ($p>0.05$).

Table 11b: Mean sensory scores of protein drink from blends of watermelon/ tomato mixed juice/soymilk

Sample	Sensory attributes				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	6.10 ± 0.02^{ef}	6.50 ± 0.01^{g}	6.70 ± 0.15^{b}	6.35 ± 0.11^{b}	6.81 ± 0.08^{b}
60:40	6.13 ± 0.83^{e}	6.53 ± 0.30^{g}	6.80 ± 0.32^{b}	6.33 ± 1.12^{b}	6.66 ± 0.34^{b}
50:50	6.72 ± 0.21^{a}	6.65 ± 0.10^{g}	6.85 ± 0.12^{b}	6.65 ± 0.13^{b}	6.75 ± 0.06^{b}
40:60	6.35 ± 0.11^{a}	6.18 ± 0.12^{g}	6.51 ± 0.03^{b}	$6.28 \pm .012^{b}$	26.80 ± 0.12^{h}
33:67	6.28 ± 0.04^{a}	5.88 ± 0.07^{e}	6.55 ± 0.01^{b}	5.85 ± 0.10^{c}	6.25 ± 0.09^{b}
CTL (control)	5.78 ± 0.13^{c}	6.23 ± 0.22^{g}	5.49 ± 0.72^{c}	6.06 ± 0.54^{g}	4.56 ± 0.08^{h}

Values represent mean scores of 15 panelists ± SD (standard deviation). Values in a column with the same superscript are not significantly different ($p>0.05$).

Table 11c: Mean sensory scores of protein drink from blends of orange/carrot mixed juices and soymilk

Sample	Sensory attributes				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	6.35 ± 0.01^{m}	6.60 ± 0.04^{j}	6.55 ± 0.10^{a}	5.85 ± 0.02^{c}	6.5 ± 0.00^{b}
60:40	6.7 ± 0.03^{m}	6.8 ± 0.07^{j}	6.65 ± 0.10^{a}	6.75 ± 0.03^{c}	6.9 ± 0.01^{b}
50:50	6.8 ± 0.11^{m}	6.75 ± 0.08^{j}	6.8 ± 0.13^{a}	6.60 ± 0.10^{c}	6.8 ± 0.08^{b}
40:60	5.75 ± 0.06^{n}	6.21 ± 0.04^{k}	6.15 ± 0.10^{a}	5.6 ± 0.01^{d}	6.7 ± 0.03^{b}
33:67	5.68 ± 0.01^{n}	5.74 ± 0.03^{k}	6.25 ± 0.01^{a}	5.5 ± 0.10^{d}	6.8 ± 0.05^{b}
CTL (control)	5.78 ± 0.11^{n}	6.12 ± 0.06^{k}	5.98 ± 0.12^{a}	6.30 ± 0.04^{c}	6.40 ± 0.02^{b}

Values represent mean scores of 15 panelists ± SD (standard deviation). Values in a column with the same superscript are not significantly different ($p>0.05$).

Table 11d: Mean sensory scores of protein drink from blends of orange/ tomato mixed juices and soymilk

Sample	Sensory attributes				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	6.40 ± 0.03^{qr}	6.25 ± 0.02^{r}	6.5 ± 0.01^{a}	6.45 ± 0.01^{b}	6.40 ± 0.10^{c}
60:40	5.85 ± 0.01^{q}	6.90 ± 0.11^{r}	6.7 ± 0.05^{a}	6.25 ± 0.05^{b}	6.50 ± 0.01^{c}
50:50	6.15 ± 0.00^{q}	6.85 ± 0.01^{r}	6.8 ± 0.11^{a}	6.25 ± 0.00^{b}	6.65 ± 0.04^{c}
40:60	5.75 ± 0.01^{q}	5.8 ± 0.10^{s}	6.6 ± 0.08^{a}	6.55 ± 0.11^{b}	6.55 ± 0.10^{c}
33:67	5.60 ± 0.06^{q}	5.75 ± 0.11^{s}	6.20 ± 0.01^{a}	6.50 ± 0.06^{b}	6.58 ± 0.03^{c}
CTL (control)	5.78 ± 0.10^{q}	6.20 ± 0.05^{r}	6.10 ± 0.08^{a}	6.40 ± 0.11^{b}	6.40 ± 0.10^{c}

Values represent mean scores of 15 panelists ± SD (standard deviation). Values in a column with the same superscript are not significantly different (p>0.05).

Table 11e: Mean sensory scores of protein drink (cashew/tomato and soymilk)

Sample	**Sensory attributes**				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	6.5 ± 0.11^{b}	6.1 ± 0.02^{ab}	6.7 ± 0.01^{d}	6.85 ± 0.03^{f}	6.2 ± 0.01^{e}
60:40	6.8 ± 0.07^{b}	7.0 ± 0.01^{a}	6.8 ± 0.03^{d}	6.70 ± 0.01^{f}	6.25 ± 0.02^{e}
50:50	6.75 ± 0.02^{b}	6.9 ± 0.00^{a}	6.7 ± 0.00^{d}	6.75 ± 0.11^{f}	6.30 ± 0.03^{e}
40:60	6.70 ± 0.10^{b}	5.9 ± 0.03^{ab}	6.30 ± 0.10^{dc}	6.5 ± 0.06^{f}	6.1 ± 0.11^{e}
33:67	6.5 ± 0.11^{b}	5.7 ± 0.10^{ab}	6.25 ± 0.06^{dc}	6.5 ± 0.01^{f}	5.9 ± 0.04^{e}
CTL (control)	5.7 ± 0.13^{ab}	6.1 ± 0.13^{ab}	5.8 ± 0.09^{dc}	6.4 ± 0.00^{f}	6.30 ± 0.06^{e}

Values in a column with the same superscript are not significantly different (p>0.05).

Table 11f: Mean sensory scores of protein drink (cashew/carrot and soymilk)

Sample	Sensory attributes				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	6.7±0.11[a]	6.75±0.02[c]	6.80±0.04[f]	6.7±0.08[d]	6.2±0.01[b]
60:40	6.8±0.08[a]	6.70±0.00[c]	7.0±0.01[f]	6.8±0.03[d]	6.60±0.05[b]
50:50	6.0±0.03[a]	6.9±0.03[b]	7.0±0.03[f]	6.8±0.05[d]	6.65±0.02[b]
40:60	6.7±0.10[a]	6.65±0.01[c]	6.4±0.00[e]	6.3±0.10[d]	5.9±0.01[c]
33:67	6.2±0.05[a]	6.40±0.01[c]	5.7±0.05[e]	6.4±0.00[d]	5.8±0.00[c]
CTL (control)	5.75±0.00[ab]	6.2±0.12[c]	5.8±0.01[e]	6.40±0.00[d]	6.35±0.02[b]

Values represent mean scores of 15 panelists ± SD (standard deviation). Values in a column with the same superscript are not significantly different ($p>0.05$).

Table 11g: Mean sensory scores of protein drink (tomato/carrot and soymilk)

Sample	Sensory attributes				
	Colour	Taste	Flavour	Mouthfeel	Consistency
67:33	6.5±0.13[ab]	5.6±0.02[d]	6.85±0.11[ef]	6.10±0.10[mn]	6.7±0.11[h]
60:40	6.8±0.07[a]	6.1±0.01[d]	6.7±0.10[ef]	6.00±0.02[n]	6.7±0.06[h]
50:50	7.0±0.11[a]	6.2±0.05d	6.7±0.11[ef]	5.80±0.01[n]	6.80±0.15[h]
40:60	6.7±0.10[ab]	5.5±0.01[dc]	6.2±0.05[f]	5.60±0.01[n]	6.7±0.03[h]
33:67	6.7±0.08[ab]	5.4±0.10[dc]	6.15±0.03[f]	5.5±0.11[n]	6.9±0.10[h]
CTL (control)	5.7±0.02[c]	6.0±0.04[d]	5.8±0.10[f]	6.4±0.03[mn]	6.5±0.15[h]

Values represent mean scores of 15 panelists ± SD (standard deviation). Values in a column with the same superscript are not significantly different ($p>0.05$).

Chemical composition (proximate composition, vitamin and mineral contents) of dietary protein drink samples.

Table 11h shows the proximate composition, vitamin and mineral contents of experimental protein drink samples. All the protein drink samples showed high moisture content including the control (88.3 – 92.14%, dry basis), which was expected because natural fruit juices have characteristic high moisture levels.

The protein contents of samples ranged from 1.80% (sample DDD, mixed watermelon + carrot/soy (50%) to 4.08% (sample AAA, mixed cashew + tomato/soymilk, 60% /40%), where samples AAA, BBB had higher protein contents than other protein drinks, because the raw vegetable juice components have been reported to contain minute protein in greater quantity than other fruit juices (Duckworth, 2006). The cashew + carrot/soy, 50%/50%), CCC watermelon (mixed + tomato/soymilk 50%/50%) and EEE (mixed orange + tomato/soymilk, 55%/45%) have higher protein contents values than control, HHH- imported protein juice (2.25%). Therefore, any of these samples is suitable as protein drink depending on desirable sensory attributes. Ash contents (0.12-0.64% range, highest in sample AAA), fat (0.66 – 1.74% range, highest in control sample), and crude fibre (0.0006 – 0.003%, highest in sample AAA) were generally low in all the protein drink samples, which is characteristic of natural juice. However, low fat content would not support rancidity of protein drink.

Carbohydrate contents were higher (7.18-7.69%) in samples AAA (mixed watermelon + carrot /soymilk, 50%/50%), FFF (mixed orange + carrot/soymilk, 60% /40%) and HHH control than others (3.02 5.5%) including BBB, CCC and GGG samples. Cashew, tomato and carrot based samples seemed to have carbohydrate constituents which were mainly simple reducing sugars (520-766 mg/100ml range) necessary for energy supply. High carbohydrate contents in watermelon and sweet orange-based protein drinks was attributed to higher natural sugar contents (7.5 8.2%) than in cashew, tomato and carrots (4.7-5.15%) as reported in previous work of the researchers (Orishagbemi, *etal*; 2015).

The energy value per litre of experimental protein juice ranged from 1,423.0KJ (sample BBB, mixed cashew +carrot /soymilk, 50%/50%) to 1,913.8KJ (sample DDD, watermelon + carrot/soymilk, 50%/50%) which varied with the sugar/carbohydrateand protein contents. This was also adequate to meet energy need of a school pupil (3 – 10 years) per day on consumption of half-litre drink (WHO 2009).

Ascorbic acid content was quite high in samples AAA (cashew/tomato/soymilk) and BBB (cashew/carrot/soymilk) with the respective values of 91.13 and 73.36mg/100ml, and low in others, including the control, HHH (27.52mg/100ml). Samples GGG (tomato/carrot/soymilk), EEE (orange / tomato/soymilk), (watermelon / CCC tomato/soymilk), AAA (cashew / tomato/soymilk), BBB (cashew/carrot/soymilk) and HHH (control) were richer in beta-carotene (0.934-2.12mg/100ml) than DDD (watermelon carrot/soymilk)and / FFF(orange / carrot/soymilk). Availability of both ascorbic acid (vitamin C precursor) and Beta-carotene (vitamin A precursor) in protein drink would serve to prevent scurvy and night blindness respectively, in regular consumers, especially school children. All the experimental protein drink samples were high in potassium (241-207mg/l) especially samples EEE, FFF and AAA.

Calcium, 11.9-23.50mg/100ml (samples FFF, DDD, EEE and HHH), but low in Zinc (0.6 1.59mg/100ml), magnesium (1.67 1.76mg/100ml) and iron (0.97 mg/100ml) Based on the nutrient composition (protein, reducing sugars, vitamin and minerals-K, Ca, Zn, Mg, Fe), samples AAA (cashew / tomato/soymilk), BBB (cashew / carrot/soymilk), CCC (watermelon / tomato/soymilk) EEE (orange / tomato/soymilk) and GGG (tomato / carrot/soymilk) were more suitable than the control (imported brand) as protein drinks for school children.

Microbiological contents /analysis of protein drink samples.

Seven (7) organoleptically desirable dietary protein drink samples out of thirty-five produced investigated for were analysed for chemical, microbiological and sensory properties to determine the most suitable for school children. Samples found to be of high qualities (in terms of nutrient content, sensory attributes, microbiological safety) include; mixed cashew, tomato/soymilk, 60%/40% (sample AAA), mixed cashew, carrot/soymilk, 50%/50% (sample BBB), mixed watermelon, carrot/soymilk, 50%/50% (sample CCC), orange, tomato /soymilk, 55%/45% (sample EEE) and mixed tomato, carrot/soymilk, 50%/50% (sample GGG). They are richer than exotic protein drink (control) in protein and micro-nutrients, and therefore any of the samples is adjudged suitable for school children in order to improve nutrition.

Table 11h: Proximate composition, vitamin and mineral contents of fresh protein juice samples (Top 7 samples and control)

Values represent mean (n=3) determinations ±SD (Standard

Analytical parameter	AAA	BBB	CCC	DDD	EEE	FFF	GGG	HHH
Moisture content (%)	90.54±1.02	90.29±0.91	92.14±0.35	91.48±0.55	91.21±1.01	91.08±0.93	92.15±0.86	88.34±0.71
Ash (%)	0.64 ± 0.22^{ab}	0.45 ± 0.10^{ab}	0.31 ± 0.01^{b}	0.12 ± 0.23^{c}	0.30 ± 0.14^{b}	0.32 ± 0.03^{b}	0.32 ± 0.03^{b}	0.33 ± 0.02^{b}
Protein content (%)	4.08 ± 0.11^{b}	2.96 ± 0.10^{a}	2.96 ± 0.11^{a}	1.80 ± 0.02^{d}	2.33 ± 0.01^{c}	1.88 ± 0.12^{d}	2.04 ± 0.21^{c}	2.25 ± 0.22^{c}
Fat (%)	0.71 ± 0.00^{bc}	0.66 ± 0.02^{bc}	1.16 ± 0.11^{e}	0.83 ± 0.04^{b}	0.77 ± 0.03^{bc}	0.53 ± 0.11^{c}	1.53 ± 0.13^{e}	1.74±0.11e
Crude fibre (%)	0.0030 ± 0.01^{d}	0.0005 ± 0.01^{c}	0.0020 ± 0.02^{d}	0.0006 ± 0.01^{c}	0.0010 ± 0.01^{dc}	0.0020 ± 0.01^{d}	0.0010 ± 0.01^{dc}	0.0020 ± 0.1^{d}
Carbohydrates (%)	3.027 ± 0.11^{e}	4.090 ± 0.11^{e}	3.428 ± 0.09^{e}	7.69 ± 0.10^{f}	5.519 ± 0.21^{ef}	7.188 ± 0.05^{f}	3.959 ± 0.23^{e}	7.338 ± 0.26^{f}
Reducing sugars (mg/100mL)	766 ± 3.12^{a}	510 ± 4.08^{ab}	740 ± 1.67^{a}	520 ± 2.89^{ab}	702 ± 8.11^{a}	620 ± 5.68^{a}	425 ± 3.01^{c}	625 ± 20.13^{a}
Ascorbic acid (mg/100mL)	91.73 ± 0.81^{b}	73.36 ± 0.52^{b}	25.22 ± 0.33^{a}	20.64 ± 0.31^{d}	$41.28\pm.028^{bd}$	24.77 ± 0.23^{d}	18.35 ± 0.17^{d}	27.52 ± 0.31^{c}
Vitamins A (As β carotene mg/100mL)	0.943 ± 0.14^{f}	0.943 ± 0.13^{f}	1.301 ± 0.11^{h}	0.886 ± 0.11^{f}	1.018 ± 0.08^{h}	0.887 ± 0.07^{f}	2.122 ± 0.12^{g}	1.037 ± 0.06^{h}
Folic acid (mg/100mL)	13.40±0.21	13.34±0.18	12.92±0.11	13.36±0.16	13.40±0.20	12.98±0.17	13.34±0.21	13.30±0.21
Potassium (mg/100mL)	207.52 ± 2.22^{cf}	193.55 ± 2.1^{c}	205.37 ± 2.5^{cf}	190.32 ± 1.0^{c}	241.93 ± 1.8^{cf}	210.75 ± 1.2^{c}	192.47 ± 0.91^{c}	181.72 ± 0.85^{c}
Iron (mg/100mL)	8.025 ± 0.23^{k}	1.338 ± 0.05^{e}	1.814 ± 0.4^{kc}	1.354 ± 0.14^{e}	1.669 ± 0.25^{e}	0.976 ± 0.06^{ke}	1.604 ± 0.07^{e}	1.929 ± 0.55^{kc}
Zinc (mg/100mL)	1.57 ± 0.01^{c}	1.30 ± 0.01^{c}	1.24 ± 0.05^{cd}	1.14 ± 0.02^{rc}	1.56 ± 0.04^{c}	0.62 ± 0.01^{r}	1.29 ± 0.03^{cd}	1.32 ± 0.11^{c}
Calcium (mg/100mL)	4.36 ± 0.11^{b}	5.40 ± 0.13^{b}	4.97 ± 0.28^{b}	12.15 ± 0.55^{bt}	12.10 ± 0.48^{bt}	23.50 ± 0.67^{t}	9.30 ± 0.24^{bt}	11.94 ± 0.33^{bt}
Magnesium (mg/100mL)	1.674±0.11	1.756±0.08	1.749±0.06	1.763±0.04	1.725±0.38	1.753±0.29	1.692±0.36	1.735±0.27
Energy (kJ/L)	1450.7±5.1	1.423.0±4.6	1.489.1±4.9	1.913.8±5.6	1.606.4 ±6.0	1.737.6±4. 8	1.586.1±3.9	2.274.1±6.8

Deviation). Means in a row with the same superscript are not significantly different (p>0.05). Sample Codes: AAA Mixed cashew/Tomato (60): Soymilk (40) BBB Mixed cashew/carrot (50): Soymilk (50) CCC Watermelon./Tomato (50): Soymilk (50) DDD Watermelon/Carrot (50): Soymilk (50) EEE Orange/Tomato (55): Soymilk (45) FFF Orange/Carrot (60): Soymilk (40) GGG Tomato/Carrot (50): Soymilk (50) HHH Imported Protein Juice (Control)

3.3 Analogue food condiments from grain legumes (Bambara nut, peanut, pigeon pea and African yam beans).

Food condiment refers to peculiar ingredient that imparts and contributes characteristic flavour, aroma and some macro/micro nutrients to food usually added during food preparation for consumption. It is glutamic acid-based, which is available in certain protein moieties. Conventional food condiments are produced by the fermentation of some grain legumes to yield high glutamic amino acid, which adds flavours and characteristic aroma to food, including African locust bean (iru), melon (ogiri), soybean (Dawadawa). Most common food condiments are chemical-based/synthetics, such as Monosodium glutamate (MSG), Onga, Maggi cubes and many more. Cumulative residuals in the body constitute health risk to consumers. Available records show that about 1.55 million metric tons assorted food condiments are consumed annually in Nigeria (NBS, 2017). There is need for variety of food condiment especially organics to safeguard consumers' health and widen choices due to ever growing population and civilization. There is necessity for value addition to underutilized legumes (e.g. pigeon pea, African yam bean, peanut) to produce industrial food ingredients for economic gains to the processors and farmers. Organic/natural food condiments are dense in protein (22 – 57%), vitamins , but low in fat and can be presented in various forms as dry, coarse, granules, powder, sauce and packaged in hermetic containers (Orishagbemi, 2016). Research reports have been made available on the elimination of undesirable flavouring locust bean and soy condiments, whereby ginger, scent leaf, lemon grass have been incorporated to absorb and mask such flavour (Adama, 2021). Therefore, objectives of this research work were to produce food condiment analogues from underutilized/neglected legumes (Bambara nut, African yam beans, peanut and pigeon pea) using natural micro flora from moistened leaf and cocoa sack, determine nutrients composition, including amino acid profile and determine organoleptic properties of condiments produced to ascertain suitability.

Samples of Bambara nut (*Vigna subterranean* L.), African yam bean (*Sphenostylis stenocarpa*), pigeon pea (*Cajanus cajan* L.) and peanut (*Arachis hypogea*) grains were purchased from retailers at Anyigba central market, Kogi State. They were identified by experts. The seeds of each legume were separately prepared into coarse particles, pressure cooked (100g/3L water) for 45 min and drained. While still hot, each was divided into two equal portions for fermentation (4 days) using two methods (calabash lined with moistened dry banana leaves for one portion and cocoa sack for second portion as sources of microbial culture for fermentation, similar to traditional method of locust bean fermentation. Such microorganisms included *Corynebacterium glutamicum*, *Lysinucum*; lactic acid bacteria such as *Leuconostoc*, *Streptococcus*, *Lactobacillus*, *Enterococcus*, *Pediococcus*, *Aerococcus* spp. Yeast (e.g. *Saccharoomyces*, *Khuyeromyces*, *Debaryomyces* species), moulds (*Penicillium*, *Geotrichum*, *Rhizopus* species). The food condiment samples (eight) were each ground, molded and dried (60^oC, in cabinet dryer with fan), cooled and packaged in heat-sealed High Density polyethylene (HDPE, 0.5mm guage). Commercial locust bean condiment (iru) was obtained and used as control sample. Each condiment sample was subjected to nutrient composition evaluation, including amino acids, sensory profile and data analysis using standard methods (Orishagbemi*et al*., 2021).

The proximate composition of analogue/imitation food condiments

Table 12 shows the nutrient contents of analogue/imitation food condiments produced

Table 12: Proximate compositions of analogue food condiments from Bambara nut (BNC), African yam bean (AYB), Pea nut (PNC), Pigeon pea (PPC) and Locust bean (LBC) (control)

Sample	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Total carbohydrate (%)
BNC1	7.76±0.22^{a}	32.05±0.14^{d}	11.62±0.01^{g}	4.41±0.46^{i}	4.31±0.11^{i}	39.85±0.60^{n}
BNC2	7.85±0.14^{a}	31.65±0.13^{d}	10.87±0.03^{g}	3.82±0.41^{i}	4.21±0.25^{f}	41.60±0.12^{n}
AYB1	8.05±0.41^{a}	29.32±0.42^{d}	9.70±0.31^{g}	3.19±0.26^{i}	4.11±0.09^{i}	54.37±0.21^{o}
AYB2	8.15±1.42^{a}	27.21±0.52^{c}	9.51±0.21^{g}	3.21±0.01^{i}	4.61±0.11^{i}	47.31±0.02^{o}
PNC1	4.85±0.07^{b}	26.41±0.04^{e}	20.75±0.07^{h}	0.89±0.07^{k}	1.08±0.04^{m}	49.75±0.02^{o}
PNC2	4.57±0.04^{b}	23.94±0.06^{f}	22.48±0.01^{h}	0.85±0.01^{k}	1.00±0.00^{m}	47.48±0.03^{o}
PPC1	9.93±0.03^{c}	27.08±0.01^{e}	1.50±0.00^{i}	1.03±0.02^{h}	1.18±0.01^{m}	59.3-±0.12^{p}
PPC2	9.36±0.13^{c}	28.76±0.2^{e}	1.67±0.05^{i}	4.86±0.25^{i}	5.85±0.12^{i}	40.85±0.30^{n}
LBC	12.30±0.14^{e}	24.13±0.03^{f}	10.32±0.32^{g}	1.10±0.01^{k}	1.20±0.00^{m}	59.60±0.21^{p}

Values are mean ±SD of triplicate determinations (SD = Standard Deviation).

Means in a column with the same superscripts are not significantly ($p>0.05$) different.

Code:

1 – Fermented using moistened dry banana leaf

2 – Fermented using moistened cocoa back

Moisture content ranged from 4.5% (PNC sample) to 12.30% (LBC control sample) which showed significant ($P<0.05$) variation among the legumes used. Traditional LBC (control) hadhighest M.C (12.30%) due to sun-drying method used (30 ± 2^oC) while others which dried in cabinet dryer at 60^oC, had lower M.C. (low water activity), due to higher drying temperature and could keep longer. The extent of biochemical complexes formed which could bind moisture lead to either increased or reduced moisture content (as in PNC, BNC, AYB and PPC samples). Similar observation and reports were made by Osman (2013) and Hassan *et al*. (2015) in their works on fermented soybean and melon condiments respectively.

Protein content was highest in Bambara condiment (31 – 32.05%), followed by African yam bean (AYB), locust bean (control) and peanut condiment with lowest value, PNC2 (23.94%). Condiments fermented with banana leaf have higher protein content in all samples, showing that it is more suitable than cocoa sack, providing the required natural microbial culture for fermentation. Higher protein content in samples fermented with moistened banana leaf might be due to the availability of appropriate natural microflora responsible for fermentation and subsequent conversion of greater metabolites resulting into higher proteins and amino acids especially glutamic acid.

Highest fat content occurred in PNC samples (20.00 – 22.88%), then followed by BNC and LBC (10.81 – 11.62%), AYB (9.51 – 9.90%) and the lowest, PPC (1.50 – 1.67%) showing significant difference. Differences in fat content was due to legume commodity effect. The crude fibre and ash contents are generally low and not affected by fermentation, while carbohydrates were very high in all the condiment samples (39 – 59% regardless of the legume, and with variation of little or no significance (p>0.05) which could be due to the use of carbohydrates present during fermentations.

Sensory profiles of food condiments

Table 13 shows the mean sensory attributes of food condiments produced (colour, taste, flavour, texture)

Samples	Sensory Attributes				
	Colour	Taste	Flavour	Texture	Overall acceptability
BNC1	$7.8{\pm}0.14^{a}$	$7.2{\pm}0.22^{e}$	$6.2{\pm}0.31^{g}$	$7.3{\pm}0.02^{h}$	$7.6{\pm}0.16^{k}$
BNC2	$7.5{\pm}0.08^{a}$	$7.1{\pm}0.18^{e}$	$7.4{\pm}0.12^{f}$	$7.5{\pm}0.11^{h}$	$7.8{\pm}0.20^{k}$
AYB1	$7.0{\pm}0.16^{a}$	$7.4{\pm}0.09^{e}$	$7.2{\pm}0.06^{f}$	$7.3{\pm}0.08^{h}$	$7.7{\pm}0.01^{k}$
AYB2	$7.2{\pm}0.21^{a}$	$7.3{\pm}0.17^{e}$	$7.4{\pm}0.12^{f}$	$7.1{\pm}0.05^{h}$	$7.3{\pm}0.10^{k}$
PNC1	$6.2{\pm}0.11^{b}$	$5.3{\pm}0.13^{d}$	$5.7{\pm}0.09^{g}$	$6.1{\pm}0.02^{i}$	$5.6{\pm}0.17^{j}$
PNC2	$5.7{\pm}0.13^{c}$	$5.5{\pm}0.06^{d}$	$5.6{\pm}{\pm}0.05^{f}$	$6.0{\pm}0.13^{i}$	$5.7{\pm}0.08^{i}$
PPC1	$7.6{\pm}0.06^{a}$	$7.3{\pm}0.02^{e}$	$7.6{\pm}0.05^{f}$	$7.8{\pm}0.01^{h}$	$7.5{\pm}0.08^{k}$
PPC2	$7.3{\pm}0.04^{a}$	$7.3{\pm}0.11^{e}$	$7.7{\pm}0.07^{f}$	$7.5{\pm}0.01^{h}$	$7.4{\pm}0.12^{k}$
LBC	$6.7{\pm}0.12^{a}$	$7.0{\pm}0.05^{e}$	$6.2{\pm}0.08^{g}$	$6.4{\pm}0.08^{i}$	$6.5{\pm}0.03^{f}$

Values are means, n = 15 panelists ± SD (SD = Standard Deviation)
Mean in a column with the same superscripts are not significantly (P>0.05) different

Code:
1 – Fermented using moistened dry banana leaf
2 – Fermented using moistened cocoa back

The taste (7.0 – 7.4 score range) and colour (7.3 – 7.8 range) of BNC, AYB and PPC were similar to that of the LBC (control sample) and significantly (P<0.05) different from sample PNC, but not objectionable. The unfermented soluble carbohydrate contents must have contributed to the taste attribute which varied among the samples. Also, natural brown pigment of peanut in PNC sample had contributed to its colour. Each condiment had its characteristics flavour, which was most cherished in PPC 1&2 condiment samples, with high flavour scores (7.6 – 7.7). Apparently, PPC, AYB and BNC were suitable alternatives to the popular locust bean condiments (iru) due to the available nutrients and sensory properties.

In summary, desirable food condimentswere produced from some underutilized legumes (Bambara nut, African yam bean, pigeon pea), similar to the traditional locust bean condiment. The nutrients content and sensory properties of these condiment samples were characterized and pigeon pea condiment was the most suitable as alternative.

3.4 Production and quality assessment of Mango custard powder(Orishagbemi and Agieni, 2022)

Custard powder is a breakfast food that usually comprises corn flour/starch, flavouring (salt, vanilla extracts) and a yellow dye. The corn flour could be partially replaced by other starches, such as potato, cassava, arrow root or wheat (Pearson, 1986). In our work on quality assessment of mango custard powder produced from ripe mango puree and corn starch, mango contributed natural sugar, flavourant and yellow pigment instead of chemical sweetener, synthetic yellow dye and flavouring. Four custard powder samples were produced from corn starch slurry and mango puree at different proportions and coded as AAA (100% corn starch), BBB (80% starch:20% puree), CCC (70% starch:30% puree), DDD (60% starch:40% puree). Each mixture was dried (70^{o}C) and milled into custard powder. The samples were then subjected to various analyses (functional, proximate composition, mineral, vitamin and sensory) using standard methods. Bulkdensity rangde (0.74 – 0.91 g/ml), water absorption capacity (3.80 – 5.20 ml/g powder), moisture content (5.22 – 6.10%), ash (1.51 – 2.30%), fat (0.78 – 1.85%), crude fibre (3.02 – 3.56%), protein (3.64 – 6.60%) and carbohydrates (81.72 – 83.18%).

Potassium, calcium, magnesium, phosphorus and iron were present in all the samples. While vitamin A ranged (0.87 – 10.45 µg/100g), vitamin C ranged (101.03 – 546.44mg/100g). Aroma rating ranged (6.50 – 8.25), colour (6.25 – 8.50), taste (7.75 – 8.00), consistency (7.00 – 8.75) and overall acceptability (8.05 – 8.50). It was found that custard produced from 60% corn starch and 40% mango puree had the highest vitamins A, C content and highest colour, taste, flavour and consistency ratings and therefore adjudged more desirable than the conventional custard (Tables 14 & 15).

Mineral composition of custard produced from corn starch and mango puree blends.

The result of the mineral composition of custard samples is presented in Table 14

Table 14: Mineral composition of custard samples

Samples	Potassium (mg/kg)	Calcium (mg/kg)	Magnesium (mg/kg)	Phosphorus (mg/kg)	Iron (mg/kg)
AAA	$31.50^{b}\pm0.33$	$88.00^{d}\pm0.17$	$35.20^{d}\pm0.44$	$32.50^{d}\pm0.45$	$16.77^{d}\pm1.20$
BBB	$50.80^{a}\pm0.12$	$194.90^{c}\pm2.09$	$77.90^{c}\pm1.23$	$163.25^{c}\pm0.56$	$18.87^{c}\pm0.89$
CCC	$50.80^{a}\pm0.41$	$281.20^{b}\pm4.89$	$112.40^{b}\pm0.65$	$215.00^{b}\pm0.78$	$41.47^{b}\pm0.91$
DDD	$54.70^{a}\pm0.32$	$342.70^{a}\pm1.03$	$137.80^{a}\pm0.21$	$223.69^{a}\pm0.65$	$55.67^{a}\pm0.22$

Values are mean ± standard deviation (n=3). Means with same superscript along a column are not significantly different ($p>0.05$).

Sample codes:

AAA = 100% Corn starch

BBB = 80% corn starch + 20% Mango puree

CCC = 70% Corn starch + 30% Mango puree

DDD = 60% Corn starch + 40% Mango puree

Vitamin A and C content of custard samples

Table 15 showed the vitamin A and C contents of the formulated custard samples.

Table 15: Vitamins A and C content of custard samples

Sample	Vitamin A (μ/RE)	Vitamin C (mg/100g)
AAA	$0.87^{d}\pm0.02$	$101.03^{d}\pm2.03$
BBB	$5.50^{c}\pm0.13$	$472.53^{c}\pm1.09$
CCC	$7.01^{b}\pm0.32$	$534.40^{b}\pm1.18$
DDD	$10.45^{a}\pm0.06$	$546.44^{a}\pm2.17$

Values are mean ± standard deviation (n=3). Means with same superscript along a column are not significantly different ($p>0.05$).

Key:

AAA = 100% Corn starch

BBB = 80% corn starch + 20% Mango puree

CCC = 70% Corn starch + 30% Mango puree

DDD = 60% Corn starch + 40% Mango puree

3.5 Organic preservation of kunun zaki food beverage(Orishagbemi *et al*., 2019)

Kunun zaki is a watery cereal-based non-alcoholic food beverage, indigenous to Northern Nigeria and widely consumed in the country due to its refreshing and nutritious qualities. It is prepared mainly from cereals (millets, sorghum and corn/maize), has low viscosity, sweet-sour taste and milk cream appearance, but characterized with short shelf-life, not more than 2 – 3 days under tropical ambient conditions. The use of synthetic chemical preservatives to extend shelf-life of foods, especially food beverages, fruits/vegetables juices, cookies, bread is practised. In most cases, expired, prohibited and over dosage of these preservatives are used, which lead to health risks and negative effects of cumulative residuals to the body. Therefore, there is need for alternative safe organic preservative suitable for kunu zaki drink. Sources of organic food additives, preservatives have been reported (Orishagbemi, 2020). The main objective was to use organic extract from African black pepper seed, which contains anti-microbial and antioxidant agents to preserve liquid kunun zaki and evaluate the qualities under ambient storage conditions.

White sorghum bicolor, sweet potatoes (white flesh) and West African black pepper were obtained from Central Market, Anyigba, Kogi State. Kunun zaki sample was prepared in the laboratory according to method described and modified, with addition of preservatives extract (Anyanwu and Nwosu, 2014). The kunun was divided into 5 equal parts as one part control and four other experimental samples treated with 5.0, 10.0, 15.0 and 20.0 g organic extract powder/litre kunun, respectively. Each was packaged in PET plastic bottles (250 ml cap in five places), pasteurized (70^{o}C, 30 min) in water bath, cooled and stored at tropical ambient temperature (28±2^{o}C) for storage (4 weeks), subjected to weekly routine inspection and analyses (physical, sensory, chemical and microbiological). Data obtained were analyzed (ANOVA) using standard technique (SPSS, Version 17).

Organoleptic attributes (colour, taste, flavour, consistency, mouthfeel) of kunun zaki in storage were found to experience some changes. The initial mean colour scores of fresh samples reduced with increase in concentration of extract powder (5.0, 10.0, 15.0 and 20.0g/L Kunun) sample. The control had highest score, but showed no significant ($p>0.05$) difference with the other samples. However, samples 10.0, 15.0 and 20.0g/L maintained initial colour for 4 weeks storage duration and significantly differed from the control with deteriorated colour. Taste and flavour attributes followed similar trend as the colour, while consistency mean scores increased with increase in the concentration of organic preservative in kunun, the control showing least score (Figure 2). The brix level, specific gravity and pH of samples were not significantly ($p>0.05$) affected by the concentration of preservative extract applied within the storage time. Total bacteria count (TBC) ranged from $8.6 \times 10^1 – 1.52 \times 10^2$ cfu/mL for experimental samples at the end of storage, which was within allowable limits and therefore safe for consumption. Lactic acid bacteria, *Saccharomyces cerevisae* and *Geotricum sp* were detected in the samples, which were responsible for slight fermentation that occurred during kunun preparation. Only 2 samples (10.0 and 15.0 g extract/L Kunun) stored for 4 weeks had the most acceptable sensory attributes and physical properties similar to the fresh kunun and therefore showing the indication of appropriate concentration of the extract for preserving liquid kunun beverage.

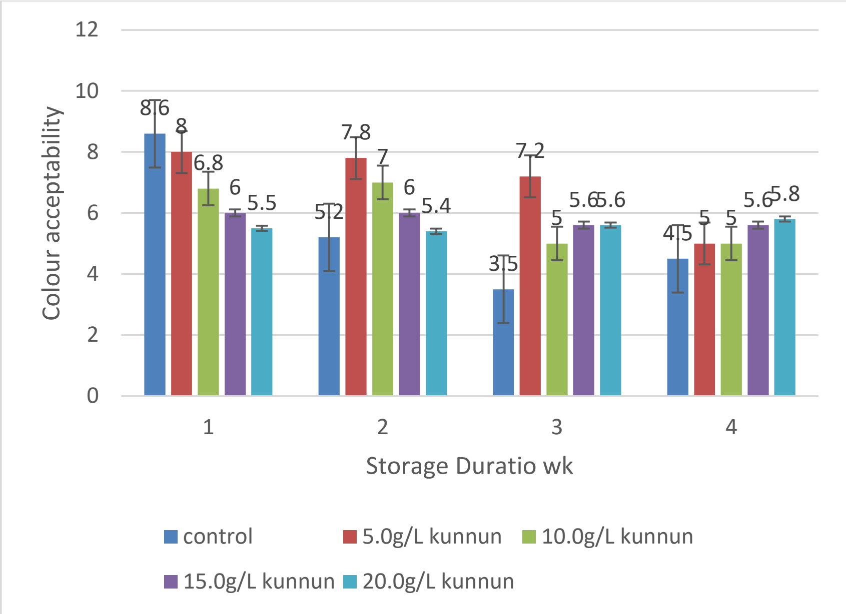

Figure 2: Mean colour scores of kunun zaki beverage with *Piper guineense* extract powder as organic preservative

4.0 By-products/wastes utilization

The major by-products or wastes emanating from plant food materials, processing are the peels, skin, shell or hull, spent pulp or chaff, seed, fibre and trimmings (some are useful raw materials after conversion to food or food related ingredients).The peel/skin/hull of groundnut seed, soybean, rice bran are suitable for high fibre biscuits, chin-chin, cookies, cashew kernel peel is suitable as alternative to hops for brewing beer. While animal's wastes such as abattoir waste is suitable for the bakery and egg shell powder as calcium supplement ingredient. In my work, bread has been successfully nutrified/fortified with abattoir waste.

4.1 Production and quality evaluation of bread incorporated with abattoir waste (Orishagbemi *et al*., 2011).

The study was designed to determine nutrient composition, evaluate the physical and organoleptic qualities of bread incorporated with abattoir waste as protein and micronutrient fortifier. Bread is a common staple food consumed worldwide. It is made of wheat flour and/or composite flours, yeast, fats, sugar, salt, water, improver. Thus, conventional bread is high in carbohydrates for energy supply, low protein and essential micronutrient contents. In Nigeria, the introduction of 10 – 20% cassava in bread in year 2005, was to definitely further reduce protein content of bread. Again, food fortification programme has become popular method of addressing the problems of macro-and micronutrients deficiencies and has been used in many countries. Bread requires fortification initiative using natural cheap sources of good quality protein and micronutrients. Consumers also cherish crust/crumb colour, texture, flavour and eating quality. For instance, yellow, orange, caramel and light brown crumb colour dominate consumer choices and natural colour is preferable because of health reasons. Characteristic pleasant bread flavour is cherished. Therefore, an attempt has been made to use abattoir waste (dried and powdered blood meal) to fortify bread, to improve nutritional values and organoleptic qualities. Fortunately, abattoir waste has not been reported anywhere to be source/carrier of HIV which causes AIDs disease. Blood meal has chocolate colour, meaty flavour and rich source of animal protein (about 800g protein/kg abattoir waste powder); high in lysine, arginine, leucine, methionine and Fe, I, P, K. It has been reportedly used as ingredients in human food and animal feed. This study was carried out to evaluate nutrient composition, organoleptic properties and acceptability of bread fortified with abattoir waste.

Fresh abattoir waste meal was collected from Anyigba abattoir, divided into two equal parts, one part kept frozen until used and the other prepared into powder (6.5%moisture content, 180 micron particle size) and packaged into heat-sealed HDPE bag for use. Both liquid and powdered abattoir wastes were each incorporated into bread recipe at four (4) different levels: 5.0%, 7.5%, 10.0% and 12.5% of flour and then baked into bread loaves, making eight experimental samples plus the control, using standard methods and procedures. The physical characteristics and chemical composition of the bread loaves were determined. Their sensory qualities as well as acceptability were also evaluated. The data obtained were subjected to statistical analysis.

Macro and micronutrient composition of bread loaves

The nutrient composition of bread loaf samples is presented in Table 15. The protein content of fortified bread samples ranged from 8.98% (sample BL1) to 13.3% (sample BP4) which were greater than protein content in sample BC (control) the conventional bread (average of 6.89% protein) by as much as 30.3% and 93.2% respectively. The values of dietary iron content ranged from 14.9 – 23.1 mg/100g loaf, greater than 12.0 mg/100g control bread sample. The increase over the control translated to 24.2% - 92.5 range. Similarly, phosphorus content had a range from 24.8 – 37.8 mg/100g fortified loaf, which were greater than value obtained in the control by 13.8% - 72.2% range. The values of iodine also ranged from 0.100 - 0.261 mg/100g fortified loaves, greater than 0.09 mg/100g control loaf, showing 50 – 125% increase.

Physical characteristics of bread loaves

Some physical characteristics of bread loaf samples are shown in Table 16. Length of a loaf ranged from 14.5 – 16.0cm, showing little variation among all the samples (BP1, BP2, BP3……..BCO), width (7.7 – 8.7 cm), height (4.1 – 5.3 cm) and weight (180 – 231 g) among the bread samples. However, values for these physical parameters except for weight were not significantly different ($p>0.05$) from the control (conventional loaf of bread).

Sensory attributes of bread loaves

The mean sensory scores of bread loaves with incorporated dried and liquid (fresh) abattoir meal are shown in Table 17. Crust colour mean scores for bread samples BP1, BP2, BL1, BL2 ranged from 6.3 – 8.1 an were rated high, while samples BP3, BP4, BL3, BL4 and BC had 2.6, 2.7, 3.1, 4.5 and 1.7 respectively were considered low.

The crumb colour mean scores were high for samples BP2, BL1, BP1 and BL2 (6.2 – 7.7 range) and very low for BP3 and BC (2.5 – 3.2 range). Sample BL1 had the highest texture rating (8.2), followed by BP1 BP2, BL2 and BC with similar rating of 5.4 – 6.6, while BP3 and BL3 had the lowest (2.9 – 3.5 mean scores).

Both taste and flavour scores followed the same pattern, in which samples BL1, BP1 and BP2 had high rating of 6.2 – 7.6 range, while BL3 and BC had very low rating of 2.9 and 1.7 respectively. General acceptability rating for samples BL1, BP2, BP1 and BL2 were high (7.4 – 8.4 range) while BP3 and BC rating were low (2.0 – 2.5).

Table 16: Nutrient composition and moisture content of bread samples

Nutrient	BREAD SAMPLES								BLOOD MEAL		
	BP1	BP2	BP3	BP4	BL1	BL2	BL3	BL4	BCO	BMP	BML
% protein (db)	----	11.01 (±0.02)	12.56 (±0.11)	13.31 (±0.13)	8.98 (±0.02)	9.42 (±0.10)	10.31 (±0.06)	10.75 (±0.05)	6.89 (±0.01)	85.01 (±0.21)	6.80 (±0.01)
Iron (mg/100g) (db)	17.0 (±0.21)	18.4 (±0.18)	22.3 (±0.16)	23.1 (±0.13)	14.5 (±0.22)	14.9 (±0.17)	15.8 (±0.09)	16.5 (±0.15)	12.0 (±0.11)	100.1 (±0.42)	37.5 (±0.17)
Phosphorus (mg/100g) (db)	26.0 (±0.11)	28.9 (±0.14)	34.0 (±0.09)	37.8 (±0.10)	24.8 (±0.011)	26.1 (±0.12)	30.3 (±0.08)	32.5 (±0.09)	21.8 (±0.12)	188.5 (±0.35)	73.5 (±0.21)
Iodine (mg/100g) (db)	0.150 (±0.08)	0.170 (±0.02)	0.240 (±0.04)	0.261 (±0.11)	0.100 (±0.09)	0.131 (±0.03)	0.172 (±0.01)	0.198 (±0.03)	0.090 (±0.04)	3.75 (±0.02)	1.88 (±0.01)
% Moisture (db)	83.95 (±0.02)	83.92 (±0.01)	83.11 (±0.01)	83.10 (±0.03)	83.96 (±0.01)	83.48 (±0.04)	83.18 (±0.04)	83.95 (±0.02)	83.12 (±0.01)	6.50 (±0.70)	91.80 (±0.32)

Values expressed as means of three determinations (±SD), BP1 = bread with abattoir waste powder (as 5.0% of flour used), BP2 = bread with abattoir waste powder (as 7.5% of flour used); BP3 = bread with abattoir waste powder (as 10.0% of flour used); BP4 = bread with abattoir waste powder (as 12.5% of flour used); BL1 = abattoir waste liquid (as 5.0% of flour used); BL2 = abattoir waste liquid (as 7.5% of flour used); BL3 = abattoir waste liquid (as 10.0% of flour used); BL4 = abattoir waste liquid (as 12.5% of flour used); BCO = Conventional/commercial bread as control; BMP = abattoir waste powder; BML = abattoir waste liquid

Table 17: Some physical properties of bread loaves

Physical property	BREAD SAMPLES								
	BP1	BP2	BP3	BP4	BL1	BL2	BL3	BL4	BCO
Weight (g)	[illegible]	180(±0.03)	189(±0.02)	198(±0.04)	201(±0.00)	213(±0.03)	223(±0.04)	234(±0.04)	149(±0.21)
Height (cm)	4.3(±0.11)	4.1(±0.08)	4.2(±0.08)	4.1(±0.00)	5.0(±0.05)	5.3(±0.02)	5.1(±0.01)	4.3(±0.03)	4.4(±0.00)
Length (cm)	16.0(±0.01)	15.9(±0.01)	16.0(±0.02)	14.5(±0.00)	14.5(±0.00)	14.5(±0.01)	15.0(±0.03)	15.3(±0.02)	8.1(±0.11)
Width (cm)	8.1(±0.04)	7.9(±0.11)	8.2(±0.01)	8.7(±0.02)	7.8(±0.11)	7.7(±0.20)	7.9(±0.06)	7.8(±0.05)	8.1(±0.11)
Crust colour	Chocolate	Chocolate	Chocolate	Dark brown	Dark	Dark	Dark	Dark	Light brown
Crumb colour	Light chocolate	Pale choco	Pale choco	Chocolate	Deep choco	Deep choco	Deep choco	Deep choco	Dull-white

Values represent means of 3 determinations (±SD)

Table 18: Mean sensory scores of bread samples

	BREAD SAMPLES								
Sensory attributes	BP1	BP2	BP3	BP4	BL1	BL2	BL3	BL4	BCO
Crust colour	6.3^{a}	7.5^{a}	2.6^{b}	2.7^{b}	8.1^{a}	5.4^{a}	3.1^{b}	4.5^{a}	1.7^{ab}
Crumb colour	6.7^{d}	7.7^{d}	3.2^{c}	4.5^{d}	7.5^{d}	6.2^{d}	3.8^{c}	4.7^{d}	2.5^{cd}
Taste	5.9^{e}	6.2^{e}	3.1^{ef}	3.5^{ef}	7.4^{e}	4.8^{e}	3.5^{ef}	4.6^{e}	1.8^{f}
Texture	5.4^{g}	6.3^{g}	2.9^{h}	4.2^{g}	8.2^{g}	5.4^{g}	3.5^{h}	4.9^{f}	6.6^{g}
Flavour	6.2^{i}	62^{i}	3.1^{i}	4.5^{i}	7.6^{i}	4.8^{i}	2.9^{i}	4.6^{i}	1.7^{j}
General acceptability	5.7^{k}	6.3^{k}	2.5^{m}	3.9^{m}	7.4^{k}	5.4^{k}	3.1^{m}	4.7^{k}	2.0^{i}

Means followed by the same superscript letter(s) in a horizontal row are not significantly different

($p>0.05$)

4.2 Production and quality evaluation of high fibre cookies (biscuit and chin-chin) from groundnut peels, rice bran and wheat).

Rice bran and groundnut peels are waste products that have been utilized as food ingredients to produce high fibre biscuits and chin-chin snacks respectively. Six (6) coded biscuit samples from composite wheat and rice bran flours were produced (rice bran levels being 0, 5, 10, 20, 30 and 40%). The nutrients, mineral contents and sensory qualities were evaluated using standard methods. The ash, crude fibre, fat and protein contents were found to increase progressively with an increase in the proportion of rice bran flour, while carbohydrates content was observed to decrease with corresponding increase in the level of rice bran flour. The sensory attributes showed less significant difference between the samples in terms of taste, appearance, flavour, texture and overall acceptability. All the samples were acceptable up to the sample containing 20% rice bran (appearance, crispiness, flavour and nutrients).

In a similar manner, high fibre chin-chin snacks, samples (six) were produced from composite wheat and groundnut peel flours (proportions of groundnut peel were 0, 5, 10, 20, 30, 40%). Apparently, chin-chin samples containing not more than 10% peel flour were acceptable in terms of appearance, taste, flavour, crunchiness and nutrients, comparable to the conventional chin-chin (0% peel flour). Benefits of fibre in food/meal include; regulation of bowel movement thereby aiding digestion and natural absorption of toxin from the bowel.

5(a) Other Research Outputs and Deliverables

Vice-Chancellor Ma, other outputs from my research works include publication of several research papers (eighty eight) in reputable on-shore and off-shore journals. Two published academic manuscripts/books, supported by TETfund, Abuja (Post-harvest Technology Management of fruits and vegetables in Nigeria, 2016 edition and Food Product Development for Beginners, 2024). Furthermore, Table 19 shows the summary of some R&D products emanating from my works.

Table 19: Summary of some R&D products from research works carried out

S/N	Raw food materials	Product description	Primary product	Secondary product	Uses
	Ripe mango	Powder	-	√	Food sweetener, Pharmaceutical industries
		Custard	-	√	Breakfast food
		Ogi	-	√	√ √
		Puree	-	√	Fruit juice/Bakery
		Bread	√	-	Baked product
		Juice	√	√	Fruit juice
		Flavour	-	√	Confectionery, soft drinks
2	Cashew kernel	Bread	√	-	Baked product
		Milk	√	-	Milk analogue
3	Cashew apple juice	Juice	√	√	Direct consumption
		Doughnut	√	√	√ √
		Wine	√	-	√ √
		Flavour	-	√	Soft drink, food flavoured
4	Onion	Flakes, powder, cubes	√	√	Foods seasoning for foods (soup, stew, meat tenderizer)
5	Banana	Powder	-	√	Food sweetener, baby foods
		Bread	√	-	Direct consumption
		Flavour			Soft drink, yoghurt, ice cream

		Ogi-banana	-	√	Breakfast/complementary food
	Pineapple	Juice	√	-	Direct consumption
		Juice powder	-	√	Food & pharmaceuticals application
		Flavour (organic)	-	√	Soft drink
	Millet	Carbonated obiolor (wort)	√	-	Direct consumption
		Kunun zaki powder	√	√	Food beverage drink
		Pop-millet	√	-	Direct consumption
	Finger millet	Malted millet			Malt-drink
		Flour			Bakery
	Guava	Juice			Direct consumption
		Flavour			Soft drink
	Bambara nut	Condiment			Food and soup ingredient
	Pigeon pea	Condiment			Food and soup ingredient
		Cheese Analogue (imitation cheese)	√		Direct consumption
	Rice	Rice-bean meal			Alternative to semovita
		Wine			For direct consumption
		Flakes			As snacks (alternative to corn flakes)
	Egg	Whole egg powder			Food application (cakes, bread)
		Egg white powder			Foam agents, other food applications
		Egg yolk powder			Food applications
	Milk	Organic,	√	√	Direct consumption

		yoghurt (liquid)			
		Yoghurt powder/flakes	√		√ √
		Nunu powder	√	√	√ √
	Termite insect	Dried & fresh	√		Direct consumption (soup), snacks
	Pawpaw	Powder		√	Food/soft drinks/beverage, pharmaceutical
		Clarified juice	√		Direct consumption
		Fish analogue		√	Soup preparation
	Almond	Edible oil			Frying and cooking
		Flour		√	Bakery
	Okra	Green okra powder		√	Cooking soup
	Carrot	Powder		√	Vitamin A supplement
2	Banana	Powder		√	Food, pharmaceuticals applications
		Flour		√	Baking, Baby foods
2	Mushroom	Powder		√	Food application
		Juice		√	Food beverages
2	Plantain	Flour		√	Bakery, fufu
2	Pineapple	Powder		√	Food & pharmaceutical applications, soft drink
		Juice powder		√	√ √
		Flavour		√	Soft drink, confectionery
		Juice	√		Direct consumption
2	Roselle calyx (red)	Carbonated juice/drink	√		Direct consumption
		Powder		√	Vegetable drink
2	Thaumatocc	Alternative		√	Food & pharmaceutical

	us danicli	protein sweetener			application
[illegible]	Potato (white, yellow)	Analogue garri	√		Direct consumption
		Flour		√	Bakery & Food sweetener
[illegible]	Cassava	Detoxified flour		√	Pasta manufacture (Noodles, spaghetti)
		Garri flavoured with coconut & fruit juice	√		Direct consumption
[illegible]	Tiger nut	Milk powder		√	Yoghurt
		Liquid milk/drink	√		Direct consumption
[illegible]	Cowpea	Rice-bean meal flour		√	Alternative to semovita (for swallow)
[illegible]	Sugar cane & beet	Organic sugar (liquid) juice		√	Bakery, confectionery, pharmaceutical applications
[illegible]	Ginger	Flavoured-bread	√		Direct consumption
[illegible]	Baobab	Powder		√	Ingredient for yoghurt premix powder
[illegible]	Dates nut	Syrup (Alternative sweetener)		√	Bakery, confectionery, food beverage
[illegible]	Melon	Edible oil		√	Margarine manufacture
[illegible]	Coconut	Milk		√	Yoghurt making
		Edible oil		√	Margarine manufacturing
[illegible]	Tea	Yogo-tea (probiotic)	√		Direct consumption

5 (b). Photos Gallery of some R & D Products


Clarified Mango Juice

Mango Custard Powder

Organic Cashew apple juice

KSU Cashew Bread

Organically preserved
Kunu zaki samples

Onion Flakes & Powder

Organically preserved bread samples

Organic Yoghourt samples

Dried Okra Slices in Package

6.0 Conclusion

The Vice-Chancellor Ma, in this lecture, I have given highlights of my research efforts on innovative food preservation through processing and storage of common food materials/commodities indigenous to Nigeria, which would contribute to reduce or minimize high postharvest losses (30 – 40%) of fresh, raw materials usually experienced along various distribution channels (farm gate, packing centres, market places, long distance transportation, homes, kitchens etc.).

The focus was on storage of harvested fresh raw food items to extend shelf-life of climacteric and non-climacteric fruits/vegetables by modified atmosphere/environment storage and packaging, gas storage, waxing techniques (which can be practiced by farmers, processors, small scale operators) without refrigeration, processing into primary or finished products, as industrial ingredients with value addition and greater economic gains.Banana, mango, cashew, pawpaw, rice, cowpea, sweet potato have been converted to different processed products, for which laboratory works were concluded, awaiting pilot scale-up and commercialization.

Foam-mat dehydration technique was extensively used combined with solar drying. Small scale food processing at farm gate and in rural areas will go a long way to curbing huge postharvest losses, especially during the climax for seasonal commodities, where poor road networks constitute challenges. Due to low volume production of food commodities, industrial processing might not be guaranteed, which requires large volume production through organized mechanization of agriculture; I have demonstrated food product development in action by production of strategic dietary protein juice for school children; imitation egg as an alternative to natural egg, imitation *garri* to replace cassava-based *garri*, from natural, organic raw materials. They are ready for pilot scale-up and commercialization. This will contribute to improve food security in our country.

My focus also has been on conversion of food wastes or by-products into usable ingredients, especially for food and related industries. For instance, abattoir waste was used for the production of nutritious and safe bread, groundnut seed peel for high fibre chin-chin snack, rice bran for high fibre biscuit/cookies. Therefore, by-product utilization is another way of loss prevention and contributing to abundant food supply.

By and large, food preservation should be encouraged at all levels to conserve the insufficient quantity produced and not to worsen the situation by annual food losses that are preventable.

7.0 Recommendations

Vice-Chancellor Ma, based on my lecture, I want to make the following recommendations and useful suggestions that would help to turn round our food security agendum which is, paramount to the country.

1. Encouragement of farm gate, small scale and household food processing in Nigeria and extend establishment of National Technology Incubation programme (NBTI) of Federal Government at the State capitals, to local government areas where food processors and entrepreneurs in the rural areas especially youthscan be trained, then start and incubate their food processing business in collaboration with NAFDAC. This could contribute greatly to curb postharvest losses, increase availability of primary products for direct consumption and secondary food products for the industries and socio-economic benefits. The cheapest solar drying

technique should be put-in-place, such as multipurpose cyclonic solar dryer.Feasible and viable R&D products highlighted be taken from laboratory shelf to pilot-up scaling and subsequent commercial productions for hunger, poverty and malnutrition prevention.

2. Establishment of cluster cottage mango processing industries in the major mango producing states in Nigeria (e.g. Kogi, Bauchi, Borno, Gongola, Sokoto, Kaduna, Kano, Niger, Plateau, Oyo, Benue, Enugu, Osun, Kwara) to maximize fully food, nutrition, agro-industrial and economic benefits of mango (a golden crop).
3. Establishment of "National Mango research centre" to anchor research programmes on mango (Value chain development programmes including agronomy, processing, utilization, economics of production). This would open up the great potentials of substantial quantities of mango available, as driver of food security, industrial and economic transformation in Nigeria and international recognition. It will be responsible for coordination of various mango research activities in the Universities,Research institutes, Polytechnics and mango associations (farmers, vendors, exporters, processors). PAAU Anyigba is a suitable location of the research centre, which is close to Ikanekpo, the largest producer of mango in Kogi State.
4. More emphasis should be placed on the production and availability of organic preservatives for processed foods (from natural sources) which are safe, to replace synthetic, chemical-based preservatives that could constitute health risks to consumers due to residual and cumulative effects.
5. The recent "Nigeria first initiative policy" of the federal government should be extended to processed food

products produced and packaged in Nigeria, whereby they are patronized by consumers at all levels and discourage importation/smuggling of their alternatives/substitutes. The businesses of local food processors are protected and will thrive. Again, import bills on such products will reduce drastically.

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My beloved parents Late Pa Orishagbemi Amos Kulu and Mrs. Abigail Musitan Orishagbemi (may your souls continue to rest in peace), for they labored to train me. I say thank you.

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I appreciate every individual present to witness my inaugural lecture today. God Almighty will give you honour beyond expectations.

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"What shall I say onto the Lord, all I have to say, thank you Lord".

Vice-Chancellor, Ma, ladies and gentlemen, I say overall "thank you" for your presence, rapt attention and remain blessed by God.

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