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Review Article

Biological Activities and Mechanisms of Actions of Bioactive Compounds (BACS) Identified in Pure and Ternary Blends of Cocoyam, Soya Bean and Bambara Groundnut Flour Using Gas Chromatography-Mass Spectrometry (GC-MS) Technique: A Review

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Abstract

Background: functional foods contain bioactive compounds (BACS) and can be sourced from both animals and plants like cocoyam (CY), soya bean (SB) and bambara groundnut (BGN). previous studies have reported various bacs in each of these plants but literature is scanty on the types and amount, of bacs in such flour blends and formulations. when in combinations as blend, anti-oxidant, interactions occur, resulting in either potentiation, additive, synergistic or antagonistic effect, depending on several various variables. their *in-vivo* bioactivities which are due to various structural features of the BACS, can be antioxidant, anti-inflammatory, hypocholestrolaemic, antimicrobial and anti-diabetic activities. in this review the various bacs identified by gas chromotagraphy (GC)-mass spectrometry (MS) technique in the various formulations of CY-SB-BGN flour blends were researched for their biological activities and reported mechanisms of actions.

Methodology: a google search of a study on bacs identified using gc-ms in cy-sb-bgn flour blend was conducted and one paper was identified. the bacs reported in the study was noted and literature search of the various biological activities of such compounds and their mechanisms of actions were conducted. the results were documented and discussed.

Results and Discussion: the study revealed that thiadiazole, stilbene, aziridine, thiourea, amphetamine/phenylethylene, artemisinin, monoterpenoids, naphthalenes, i,4-diazpanes, phenols and flavanoids were the identified bacs in cy-sb-bgn flour blend formulations with both the pure and ternary blends showing different family classifications of compounds and different types of compounds in one family class. the biological activities and mechanisms of actions included antimicrobial, antioxidant, antiinflammatory and antidiabetic activities with reported mechanisms of actions for each of these *invivo* activities.

Conclusion: there are bacs in cy-sb-bgn formulations which are reported from studies to possess anti-microbial, anti-inflammatory, anti-oxidant and anti-diabetic properties *invivo,* with very established mechanisms of actions, making the use of such plant foods in disease management scientific, hence the recommendation of such plant foods use as adjunct in chronic disease management.

Keywords: Bioactive compounds, Plant foods, Cocoyam, Soya Bean, Bambara Groundnut

1. INTRODUCTION

Functional foods are foods which in addition to their nutritional value contains others constituents like biologically active substances such as antioxidants, minerals, vitamins, presbiotics that have health benefits[1]. Functional foods from medicinal plant foods are useful in managing many diseases due to the presence of bioactive compounds[2]. BACs are not only seen in plants foods but also in animals. These animal and plant sources include cocoyam, shrimps, egg, and legumes[3-6]. The biological activities of these bioactive compounds ranges from antioxidant, anti-inflammatory, hypocholestrolaemic, antimicrobial and anti-diabetic activities[7-20]. Such bioactivities are due to various structural features of such compounds among which are the chain length, hydrophobicity, molecular charge and the side chain bulkiness of the amino acid residue[18,21]. Recent studies on Bambara groundnut (*Vigna subterranean*) Soya Bean (*Glycine max. (L) Merrill*) and cocoyam (*Colocasia esculenta*) in pure and ternary blends show that these plant food formulations contain bioactive compounds (Uro-Chukwu & Uro-Chukwu, unpublished Bench work).

The recent findings collaborate previous studies which equally reported the presence of various bioactive compounds in such plant foods[14,15, 20,22].

Besides containing these BACS, cocoyam, bambara groundnut and soya bean are ready sources of macro-nutirents and some other micro-nutrients, are readily available in poor-resource countries and cheap[23-27]. When the flour are blended, the available BACs in various concentrations in combinations, can exhibit antagonistic or synergistic effects, with the net outcome being more or less high potency in anti-inflammatory, antioxidant, anti-diabetic or immune-stimulatory effects[28-31].

Antioxidant interactions *in vivo* and *in vitro* have been documented irrespective of the sources of the bioactive compounds. The interaction between multiple agents can result in either potentiation when one of the flour mix is an inactive compound but improves the efficacy of the active compound [32,33], additive interactions when the two or more compounds are active and their total effect equals sum of the efficacy of the single components of the combination but if the sum is of greater effect, it is said to be synergistic and if lower, it is antagonistic[32]. The combination mechanism depends on several various variables including concentration, ratio, the medium in which the reactions occur, the spatial orientation, the form of radical initiators, interfering substances and the prevailing microenvironment for the reactions[34]. Such combination effects have been shown in marine-derived BACs found to have advantages in managing obesity[35]; anti-inflammatory and antioxidant activities[30,31] and anti-cancer[36,37]. Similar work have been conducted in dietary phytochemicals such as BACs-derived from cocoyam, soybean, Bambara groundnuts, fruits and vegetables when combined have also shown similar combination effects and *in vivo* and *in vitro* activities as demonstrated by marine BACs[38,39].

Using unripe plantain and millet dietary feed blend in rats in which alloxan was used to induce diabetes, Nnadi and colleagues were able to document a decrease in the concentration of blood glucose by 42.34% - 50.95% and that such actions were likely due to the presence of flavonoids and phenols[28]. Experimenting with Dioscorea dumentorum (bitter yam) and digitaria exiles (*acha*) in diabetic rats, Onwuchekwa and colleagues reported hypoglycemic and hypolipidemic properties of the blend[29]. Study on the consumption of cocoyam-cowpea-plantain flour blend by healthy individuals was reported to result in better glycemic index and blood lipid profile when the flour mix was given in 50:50 ratio[40]. Equally acompounded breakfast product of African yam bean (*Sphenostylis sternocarpa*)-sorghum (*Sorghum bicolor L.*)-unripe plantain (*Musa paradisiaca L.*) flour mix in graded ratios was found to have hypoglycaemic, hypolipidemic and hepatoprotective effects on diabetic rats[41].

Soya bean flour blends were also documented to exert anti-hyperglycemic activities in diabetic animals. In a study by Akinjayeju and team, dough produced from maize-soybean-millet flour blend was documented to have glycaemic properties and anti-diabetic potentials in diabetic rats[42]. Optimized dough meal from plantain-soybean cake-rice bran flour blend fed on STZ Induced diabetic rats resulted in higher endogenous antioxidant enzyme capacity since the reduced glutathione (GSH), catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPx), and glutathione transferase (GST) in the liver, were increased, while reducing the lipid peroxidation biomarker, malondialdehyde (MDA), the myeloperoxidase (MPO) and the xanthine oxidase with the increased alpha-amylase and alpha-glycosidase enzyme activities[43]. Similarly anti-diabetic activity was established in optimized blends produced from matured plantain-soya cake-wheat bran flour mix by researchers who reported significant α-glucosidase, α-amylase inhibition and highly reduced approximate values of glycemic index[44]. In another work, reported anti-hyperglycemic properties from Plantain-defatted soybean-tiger nut flour mix fed on diabetic rats[45].

Bambara groundnut flour blend have also shown hypolycemic potentials. When wheat whole bread were substituted with Bambara groundnut to get a wheat-bamabara groundnut, 25%:75% respectively, flour blend, the experimental diabetic rats recorded higher nutritional composition, growth indices, free radical scavenging potentials, ability to modulate carbohydrate hydrolyzing enzyme and lower glycemic index/ load[46].Similar improved protein content, haematological properties and nutritional status of alloxan-induced diabetic rats were fed with a blend of African bean flour, Bambara groundnut flour, and fermented popcorn[47]. When Bambara groundnut flour, finger millet and *Lecaniodiscus Cupanioides* (Khain) flour were mixed and fed on alloxan-induced diabetic rats, the composite flours led to significantly decreased blood glucose concentrations, liver enzymes levels, weight loss and better lipid profile, urea and creatinine levels when compared to the positive controls[48].

The biological activities of flour blend therefore depends on the composite flour composition and several other factors in the microenvironment. The aim of this review therefore is to report the biological activities and mechanisms of actions of the various BACs identified in a current study that documented using GC-MS, in a cocoyam-soya bean-bambara groundnut flour blend, with a view to understanding the basis for their *invivo* actions of such formulations in the management of non-communicable diseases like Type 2 diabetes mellitus.

2. Bioactive Compounds in CY-SB-BGN Flour Blend

The various bioactive compounds identified in the GC-MS analysis of different pure and ternary blends of cocoyam-soya bean-Bambara groundnut flour according to the study done by Uro-Chukwu & Uro-Chukwu, (unpublished Bench work) were thiadiazoles, stilbene, aziridine, thiourea, amphetamine /phenylethylene, artemisinin, monoterpenoids, Naphthalenes, 1,4-diazepanes, phenols and flavanoids (Table 1).

The commercial rat feed (formulation RF) contained BACs like **thiadiazol** (Piperidine, 1, 2-dimethyl, 1, 2, 3-Thiadiazole-4-carboxylic acid, hydrazide, **Phenols** (Phthalan (Isocoumaran) or 1, 3-dihydro-2-benzofuran,

2-Methoxy-4-vinylphenol, Vanillin) and **carboxylic acid** (Dibutyl phthalate) (Table 1). Other formulations (1 - 7) equally contain BACs in varying concentrations (Table 1). Formulations 1 contained mainly phenolics and carboxylic acids with an additional aziridine compound [N-Isopropoxy-2-carbomethoxyaziridine] while thiourea, phenols and carboxylic acids were the identified BACs in Formulation 4 (Table 1). Formulation 6, contained Aphetamine and Phenylethylamine, Phenols, (E)-Stilbene; Dibutyl phthalate and an artemisinin while Formulation 7 had 1,3-Benzenediol, 2-chloro, 4-Hydroxy-3-methylacetophenone, Butylated Hydroxytoluene, 1-methoxy-2-(methylthio), [Thiophene, tetrahydro-2-methyl] and Phthalic acid, butyl isohexyl ester as the bioactive compounds (Table 1). The BACs compounds in formulations 5 were phenolics and diazepanes, and in formulation 2, phenolics and carboxylic acids in addition to thiadiazol (Tables 1). In Formulations 3, the BACs were 4,7,7-Trimethylbicyclo[2.2.1]heptan-2-one O-allyloxime), and 2(1H)-Naphthalenone, octahydro-4a-methyl-7-(1-methylethyl)-, (4aα,7β,8aβ).

These BACs though present in all the formulations, a critical observation showed that while some formulations contained some of the common BACs, others contained some rare ones like aziridine, artemisinin, and thiadiazol in formulations 1, 2 and 6 respectively. Secondly some of these formulations have different phenolics than others as seen in formulations 1, 2, 3, 4, 5 and 6, with formulation 3 containing an additional phenolic derivative. Thirdly only formulation 2 had Quinoline,2-phenyl, a flavonoid as an identified BAC. Fourthly, the number of different BACs contained in each formulation varied. While Formulations 2, 3, 6 and RF, had six different BACs contained in them, formulations 4 and 5 had three and formulations 1 and 7 had two and five different compounds respectively.

Of the different compounds contained in each formulations, the classes of the compounds were also different. In the commercial rat feed, Formulation RF, the six varied compounds belong to three classes, namely phenolics, carboxylic acids and thiadiazol. In these classes, the phenolics had three different compounds in the family while two compounds, that is, Piperidine, 1, 2-dimethyl and 1, 2, 3-Thiadiazole-4-carboxylic acid, hydrazide (Table 1), are in the family of thiadiazole. In formulation 3, there are four classes with three different compounds in the phenolic family, while in Formulation 2 and 6 there are five and four classes of compounds respectively, with two different phenolic compounds in the phenolic class (Table 1).

Among the formulations with three groups of BACs, Formulations 4 and 5, there are two and three classes of compounds respectively, with the former containing two different phenolic compounds and formulation 4 containing only one. Formulation 7 which had two compounds belonging to two different classes had no phenolic compound while formulation 1 with five different compounds in three classes has three different phenolic compounds as constituents of the BACs (Table 1).

Earlier studies reported the presence of isoflavones, oxalates, phytic acids and bioactive peptides in soybean. The Isoflavones are of three classes, namely the glucosides like daidzein, genistein and glycitin; the acetyl form of glucosides; malonyl glucosides and the unconjugated aglycones[49]. Inositol hexaphosphate (IP^6), myo-inositol and inositol phosphate are other BACs in soybean[50]. In cocoyam, the phytochemicals, polyphenolic compounds such as flavonoids, tannin and alkaloids were present in cocoyam and these phytochemicals have hypoglycemic and antioxidant properties[14,15,20]. Bambara groundnut phytochemical contents include phenolics like quercetin, quercitrin, iboquercitrin, kaempterol, rutin, myricetin, luteolin, catechin, epicatechin, caffeic acid, ellagic acid, cholorogenic acid and gallic acid[22,51]. Literature is scanty on the BACs present in various combinations of Cocoyam-soya bean-Bambara groundnut flour blends. Hence the need to review the available BACs in the published work and their *invivo* activities.

Table 1: GC-MS Results of Various CY-SB-BGN Formulations

Formulations	Formulations Constituents	Name of Bioactive Compounds Identified	Family Classifications
1	16.6%CY + 16.6%SB + 16.6%BGN + 50%RF	4-Hydroxy-2-methylacetophenone	Phenols (Guaiacol)
		Phenol, 2,6-dimethoxy	Phenolics
		4-Methyl-2,5-dimethoxybenzaldehyde	Phenolic Aldehyde
		1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	Carboxylic acid
		N-Isopropoxy-2-carbomethoxyaziridine	Aziridine
2	12.5%CY + 12.5%SB + 25%BGN +50%RF	[1,3,4]Thiadiazol, 2-amino-5-(2-piperidin-1-ylethyl)-	Thiadiazol
		p-Fluorophenyl maleic anhydride	Benzene

		2-Methoxy-4-vinylphenol	Phenols
		Phenol, 2,6-dimethoxy	Phenols
		Quinoline,2-phenyl	Flavonoids
		Phthalic acid, butyl 2-ethylbutyl ester	Carboxylic acid
3	25%CY + 12.5%SB + 12.5%BGN + 50%RF	1,3-Benzenediol, 2-chloro	Phenols
		4-Hydroxy-3-methylacetophenone	Phenols (Guaiacol)
		Benzene, 1-methoxy-2-(methylthio)	Benzene
		Butylated Hydroxytoluene	Phenol derivative
		Thiophene, tetrahydro-2-methyl	Mono-cyclic heteroarene (Furan)
		Phthalic acid, butyl isohexyl ester	Carboxylic acid
4	12.5%CY + 25%SB + 12.5%BGN + 50%RF	Hydrazinecarbothioamide (2-[1-(4-nitrophenylethylidene)	Thiourea
		2-Methoxy-4-vinylphenol	Phenols (Guaiacol)
		Stilbene (1,2-diphenylethylene)	Carboxylic acid
5	0%CY + 0%SB + 50%BGN + 50%RF	2,6-dimethoxy phenol	Phenolics
		Vanillin (4-Hydroxy-3-methoxybenzaldehyde)	Phenolic Aldehyde
		Homopiperizine (1,4-Diazepanes)	1,4-Diazepanes
6	50%CY + 0%SB + 0%BGN + 50%RF	Benzofuran, 2,3-dihydro-	Amphetamine & Phenylethylamine
		2-Methoxy-4-vinylphenol	Phenol
		Phenol, 2,6-dimethoxy	Phenol
		(E)-Stilbene	Carboxylic acid
		Dibutyl phthalate	Carboxylic acid
		Dihydroartemisinin, 10-O-(t-butyloxy)-	Artemisinin
7	0%CY + 50%SB + 0%BGN + 50%RF	4,7,7-Trimethylbicyclo[2.2.1]heptan-2-one O-allyloxime	monoterpenoid
		2(1H)-Naphthalenone, octahydro-4a-methyl-7-(1-methylethyl)-, (4aα,7β,8aβ)	Naphthalene
RF	0%CY + 0%SB + 0%BGN + 100%RF	Piperidine, 1,2-dimethyl	Thiadiazol
		1,2,3-Thiadiazole-4-carboxylic acid, hydrazide	Thiadiazole
		Phthalan (Isocoumaran) or 1,3-dihydro-2-benzofuran	Phenols
		2-Methoxy-4-vinylphenol	Phenols
		Vanillin	Phenolic aldehyde
		Dibutyl phthalate	Carboxylic acid

CY = Cocoyam; SB = Soya Bean; BGN = Bambara Groundnut; RF = Commercial Rat Feed

Source: Uro-Chukwu & Uro-Chukwu (unpublished Bench work)

3. Biological Activities and Mechanisms of Actions of the identified BACs

In the documented study of Uro-Chukwu & Uro-Chukwu (unpublished Bench work), the BACs present were thiadiazoles, stilbene, aziridine, thiourea, amphetamine /phenylethylene, artemisinin, monoterpenoids, Naphthalenes, 1,4-diazepanes, phenols and flavanoids Each of these compounds have biological activities that are of health benefits to the individuals. Thiadiazoles for instance have antimicrobial, anti-inflammatory and hypoglycemic effects. The antimicrobial effects of

thiadiazole occur as a result of its nitrogen-sulfur heterocycles as structural[52], while the strong aromaticity of the ring are responsible for the anti-inflammatory actions[53]. In exerting an anti-hyperglycemic effect, thiadiazole works by the inhibition of carbonic anhydrase activity[54].

The biological activities of stilbene compounds such as carboxylic acids include reduction of insulin resistance and weight gain, which it accomplishes through Inhibition of Protein-tyrosine phosphatase 1B (PTP1B)[55]. Stilbene also Inhibits adipogenesis and lowers fat accumulation by reducing the PPARγ and C/EBPα levels and by the expression of Cyclin A and cyclin-dependent kinase 2 (CDK2)[56] and upregulation of GLUT4 [57]. It attenuates obesity-induced inflammation in adipocytes through the reduction in inflammatory cytokines TNF-α, IL-6 and monocyte chemo-attractant protein-1 (MCP-1)[58]. Stilbene prevents insulin resistance development by the inhibition of NLRP3 inflammasome activity[59] and activation of SIRT1[60] and by inhibiting the induction of autophagy TXNIP[61]. Stilbene equally inhibits overexpression of IL-6 through the down-regulates NF-κB and activator protein-1 (AP-1) in different cells[62]. It prevents release of type 1 (IL2, IFN-γ, and lymphotoxin) cell mediated inflammatory response and type 2 (IL4, IL5, IL10, and IL13) antibody-mediated immune response T cells, by Inhibiting the proliferation of CD4+ and CD8+ T cells[63]. Through the up-regulation of pAMPK with a resultant modulation of the expression of AMPK and Sirt1[64] and up-regulation of Caveolin-1[21], stilbene, ensures cellular energy homoestasis, lipolysis and fat loss. By the activation of transcription factor 4 (ATF-4) and Tribbles Pseudokinase 3 (TRIB3), stilbene lowers endoplasmic reticulum stress and improves Insulin sensitivity[62,65] an effect that is further enhanced by the downregulation of protein kinase-like ER kinase (PERK) and eukaryotic initiation factor 2 alpha (eIF2 alpha)[66,67].

Aziridine has an antimicrobial effect, which has been linked to the presence of sulphur atom in its (S)-configuration[68], just like in thiourea, but in the case of the latter the presence of the benzyl group and lipophilicity is responsible for the action[69,70]. Thiourea also has an anti-inflammatory effect that is associated with its potent inhibition of 5-LOX[71,72] as well as its blood glucose regulation through the inhibition of α-glucosidase, AGEs and PTP1B[73]. Amphetamine has anti-obesity and weight reduction effect as a result of its action on the hypothalamic receptors that results in the release of norepinephrine, dopamine and serotonin increasing CNS activity and resting energy expenditure[74].

Artemisinin improves insulin resistance and Islet cell function[75] and exerts anti-obesity action[76]. It causes the reversal of hepatic *de novo* lipogenesis and lipid accumulation through the inhibition the over-induction of hepatic sterol regulatory element-binding protein 1 (SREBP1)[77,78] carbohydrate-responsive element-binding protein (ChREBP)[79]. It alters the direction of adipocyte differentiation, due to its action of glucose transporter-4 (GLUT4) and vascular endothelial growth factor (VEGF) levels to achieve this[80]. Artemisinin inhibits lipid accumulation during adipose differentiation by reducing the expression/activity of CCAAT/enhancer-binding proteins (C/EBPs) and peroxisome proliferator-activated receptors (PPARs)[81] and inhibition of the expression and activity of gelatinase matrix metalloproteinase (MMP)-2, which is important to the development of adipose tissue[82]. It also inhibits accumulation of lipids by activating brown adipose tissue and brown white adipose tissue, as well as by the activation of the p38 mitogen-activated protein kinase (MAPK)/activating transcription factor-2 (ATF2) axis and deactivating the Akt/mTOR pathway[83]. Artemisinin exerts anti-inflammatory activity through different mechanisms, including by the inhibition of the secretion of TNF-α and IL-6 in undifferentiated adipose tissues and through the reduction of the cyclo-oxygenase-2 (COX-2), promotion of the AMP-activated protein kinase (AMPK) activity and the down-regulation of the expression of inflammatory factors[75]. It equally inactivates NFkB[84]. Artemisinin can equally restore the functions of the pancreatic β-cells by inhibiting α-glucosidase activity[85], increasing insulin secretion by the up-regulation of the expression of SIRT1 in islet ß-cell[86] and by reversing the unbalanced ratio of insulin, glucagon, and somatostatin content in islets of Langham[87].

Monoterpenoids exert anti-diabetic activity through the inhibition of α-amylase and α-glucosidase activities[88,89] It also reduces oxidative stress and stimulates the activities of the antioxidant enzymes including catalase and superoxide dismutase[90]. It also inhibits adipogenesis, increase in metabolic rate, reduction of weight gain, and enhanced tolerance to glucose, through its inhibitory action on the retinaldehyde dehydrogenase enzyme[91]. Monoterpenoids improves glycogen content in hepatocytes and preserves the histology of hepatic and pancreatic β-cells through its inhibitory activity on GLUT2[92]. Finally through its anti-inflammatory actions, it maintains endothelial functions[93].

Naphthalene decreases fasting blood glucose and serum lipid levels, enhancing insulin sensitivity, and ameliorating hepatic steatosis by inhibiting FABP4[94]. It equally exerts antimicrobial activity by the stimulation of heme oxygenase-1 expression[95,96] while its inhibition of the pro-inflammatory mediators such as nitric oxide, interleukin-6, and TNF-α is responsible for the anti-inflammatory actions[97].

1,4-Diazepanes reduces the concentration of circulating active cortisol and corticortisone in the blood and hence insulin resistance and metabolic syndrome, an action achieved through its organ specific 11 beta-HSD1 inhibitor in the adipose tissues[98]. In the case of Phenolics, the antioxidant activities are due to scavenging radical species such as ROS/RNS, suppressing ROS/RNS formation by inhibiting some enzymes or chelating trace metals involved in free radical production and up-regulating or protecting antioxidant defence system[99], while its anti-inflammatory actions are as a result of Inhibit transcription factors such as NF-κB and blocking MAPK-mediated pathway closely linked to inflammation[100]. It also inhibits pro-inflammatory cytokines release, inhibits enzymes such as COX-2,

lipoxygenases (LOX), inducible nitric oxide synthase that mediate inflammatory processes[100,101-105].

The anti-diabetic effects of phenolics stems from the activation of the 5' adenosine monophosphate-activated protein kinase (AMPK) pathway to stimulate glucose uptake by the skeletal muscle cells thereby reducing fasting blood glucose[106,107], inhibition of gluconeogenesis and enhancement of glycogenesis[108], elevation of the α-amylase and α-glucosidase inhibitory activity[109] and by improving the glucose absorption capacity via the increase of the expression of hepatic insulin signaling proteins like phosphatidylinositol-3 kinase, Akt/protein kinase B, insulin receptor substrate 1, and glucose transporter 2[110].

Flavonoids equally exerts anti-oxidant, anti-inflammatory and anti-microbial effects. Its anti-oxidant effects are due to a direct scavenging activity, inhibition of ROS formation through the chelation of trace elements, inhibition of the enzymes that participate in the generation of free radicals like glutathione *S*-transferase, microsomal mono-oxygenase, mitochondrial succinoxidase, NADH oxidase, and xanthine oxidase and activation of antioxidant defences like upregulation of antioxidant enzymes with radical scavenging ability[111,112]. It exerts anti-inflammatory action by acting as inhibitors of protein kinases, phosphodiesterase and transcription factors and by modulating the activity of the immune cells[111]. The antimicrobial effect is by the induction of bacterial membrane disruption and inhibition of several processes such as biofilm formation, cell envelope synthesis, nucleic acid synthesis, electron transport chain, and ATP synthesis[113] and by blocking the binding and penetration of viruses into cells, interference with viral replication or translation, and preventing the release of the virus[114].

Conclusion:

Bioactive compounds present in cocoyam-soya bean-bambara groundnut include those earlier reported in the individual plant foods in previous studies in addition to some other compounds. A review of the biological activities of such BACs showed that the formulations have documented anti-microbial, anti-inflammatory, anti-oxidant and anti-diabetic properties *invivo*, with very established mechanisms of actions. This implies that the scientific basis for the use of such plant foods in the management or as a treatment adjunct for some non-communicable diseases are well established. It also follows that such medical plant foods can have a place in the amelioration of insulin resistance development and prevention of metabolic syndrome, aside its role in managing type 2 diabetes mellitus. It is therefore suggested that patients who are at the risk of development of these chronic illnesses, can find the consumption of these food plants useful.

Authors` Contributions:

Henry CU =Topic design, Proposal writing, Literature search, draft manuscript

Franklyn CU = Data Entering, Statistical analysis, draft manuscript

Frances CU = Study Analysis, Literature search

All authors read and approved the final manuscript

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