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REVIEW PAPER

THE CHEMICAL COMPLEXITY OF YAJI: A NIGERIAN SUYA MEAT SAUCE INDUCING SCIENTIFIC INVESTIGATIONS

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ABSTRACT

In various published studies, *Yaji* has been described as 'a complex Nigerian meat sauce' based on its numerous active ingredients. This complexity tag, coupled with the high consumption rate as well as the large consuming population, have triggered a series of research efforts aimed at determining the positive and negative potentials of *Yaji*. Currently, there are numerous scientific and analytical reports in this direction. But as revealing as the reports have been, none of them has been dedicated to unveiling the chemical bases upon which *Yaji* is described as 'complex'. Therefore, for completeness sake as regards the knowledge on *Yaji*, this review paper examines its chemical complexity with a view of providing information that would justify the need for the regulation of *Yaji* production on one hand, and the need for a moderated consumption on the other; considering the chemical interplay that might be associated with an excessive consumption of *Yaji*.

Key Words: *Suya* sauce, chemical complexity, excessive consumption, *Yaji*, *Yaji*-spices, *Yaji*-additives

INTRODUCTION

Suya and *Yaji* have been on the spotlight for some years now and as such, have attracted various assertions. According to Igene and Mohammed (1983), *Suya* is "a popular, traditionally processed, ready to eat Nigerian meat product, which may be served or sold along streets, in club houses, at picnics, parties, restaurants and within institutions". Omojola (2008) described it as "one of such intermediate moisture products that is easy to prepare and highly relished", while Uzeh et al. (2006) identified it as "a mass consumer fast food whose preparation and sales along the streets, are usually not done under strict hygienic condition". These attributes of *Suya*: 'popular', 'highly relished' and 'a fast consumer fast food' have triggered several investigations on its sauce called *Yaji*.

Chemically, *Yaji* is a complex physical mixture of groundnut cake powder, additives and spices (Okonkwo, 1987). The additives are table salt and *Ajinomoto* containing sodium chloride and monosodium glutamate (MSG) as active principles respectively, while the spices that include ginger, cloves, red pepper, and black pepper, contain gingerol (Witchtl, 2004), eugenol (Krishnaswamy and Raghuramulu, 1998), capsaicin (Collier et al., 1965), and piperine (McGee, 2004) as active principles respectively.

Bringing these active principles into perspective, one can theorize therefore, that an excessive consumption of *Yaji* implies a combined excessive consumption of each of the active principles in *Yaji*, which in turn, queries what the combined effects might be. Consequently, several questions are been raised and answers to most of the questions remains unanswered; while the urgent need to provide answers cannot be overemphasized. Moreover, the global mass consumption of spices is well known (Gopalan et al., 1971; Thimayamma et al., 1983) and this makes it reasonable to consider the potential synergistic effects of mixtures of spices within the context of the total diet (Kochar, 2008).

Nevertheless, scientific efforts to determine the effects of *Yaji* on body organs are ongoing and recent findings have shown that an excessive consumption of *Yaji* is potentially harmful (Nwaopara et al., 2004; 2007a, b; 2008a, b; 2009a, b; 2010a, b; 2011; Akpamu et al., 2011a, b, c). Some of the histological findings indicates that *Yaji* has the capacity to induce pancreatic necrosis (Nwaopara et al, 2004), hepatic necrosis (Nwaopara et al, 2007a), Oligodendroglioma (Nwaopara et al, 2009b), neurodegeneration (Nwaopara et al, 2010a; 2011) and hypoxia-ischemia (Nwaopara et al, 2010b). Another study suggested too, that *Yaji* is capable of inducing renal damage via a mechanism that might be associated with mast cell invasion of the renal cortex interstitium and subsequently, the triggering of renal fibrosis (Nwaopara et al, 2008b).

Unfortunately however, none of these scientific studies have been dedicated towards unveiling the chemical bases upon which this sauce is tagged 'complex'. For completeness sake therefore, this review paper examines the chemical complexity of *Yaji*, with the hope that steering-up consciousness among the consuming population, would expose the depth of chemical interplay that might be associated with an excessive consumption of *Yaji*.

THE CHEMICALS IN YAJI

As stated previously, *Yaji* is a physical powdery mixture of black pepper, clove, ginger, groundnut cake powder, monosodium glutamate (MSG) and salt. Chemically however, each of these constituents contains arrays of chemical compounds or elements. In black pepper (*piper nigrum*) are piperine, essential oils like terpenes, and alkaloids that include the pungent tasting chavicine and piperidine (Bentley and Henry, 1980; McGee, 2004). The terpenes include pinene, sabinene, limonene, caryophyllene, and linalool and these contribute to its aroma (McGee, 2004). Black pepper also contains large quantities of sodium, manganese, potassium, zinc and iron (Lavilla et al., 1999; Kirmani et al., 2011).

Cloves (*eugenia caryophyllis*; *syzgium aromaticum*) contain a significant amount of an active component called eugenol, which has made it the subject of numerous health studies (Krishnaswamy and Raghuramulu, 1998). Other components of cloves include beta-caryophyllene (Ghelardini et al, 2001) and a variety of flavonoids including kaempferol and rhamnetin (Friedman et al, 2002; Krishnaswamy and Raghuramulu, 1998). Cloves also contain iron, potassium, zinc, manganese and Copper (Lavilla et al., 1999; Kirmani et al., 2011).

Although ginger varies significantly between plant varieties and regions in which it is grown (Bruneton, 2000; Gruenwald, 2004), it contains volatile oils (zingiberene, zingiberol, D-camphor), shogols, diarylheptanoids (gingerenones A and B), gingerols (Wichtl, 2004). Ginger also contains iron, calcium, and phosphorus (ICMR, 2003) as well as magnesium and manganese (Chaudbury et al., 2007).

Red pepper (*capsicum annum*) contains capsaicin (8-methyl-N-vanillyl-6-noneanide) (Collier et al, 1965), carotenoids - capsanthin, capsorubin and carotene (Govindarajan, 1968; Saber, 1982) and steroidal saponins known as capsicidins, which is found in the seed and root (Saber, 1982). It also contains iron, zinc, and potassium (Nkansah and Opoku-amoako, 2010).

Groundnut (*apios americana*) contains oil, protein, fatty acids and carbohydrate (Nagaraj, 1988; Jambunathan, 1991). It also contains some mineral elements like potassium, sodium, calcium, phosphorus, and magnesium (Mason et al, 1969; Aremu et al., 2006) with low quantities of copper, manganese and zinc (Aremu et al., 2006).

Monosodium glutamate (MSG) contains 78% glutamic acid and 22% sodium and water (Adrenne, 1999), while table salt contains 97% to 99% of sodium chloride (Tesco, 2010). Salt also contain additives such as potassium iodide, sodium iodide, or sodium iodate, (McNeil, 2006) as well as sodium fluoride or ferrous fumarate (Westphal et al., 2002).

PHOTOCHEMISTRY OF *YAJI*-SPICES

Naturally occurring compounds in spices include sulphur compounds, terpenes and terpene derivatives, phenols, esters, aldehydes, alcohols and glycosides (Russel and Gold, 1991; Davidson and Baren, 1993; Deis, 1999). According to Kochhar (2008), the fragrant, aromatic and pungent character of many spices is caused by essential oils that include terpenes, sesquiterpenes, pinenes, alcohols, esters, ketones, and aldehydes. Certain spices have alkaloids such as capsaicin, piperine, chavicol and saponins like trigonelline, which are responsible for the pungent and bitter taste of peppers and fenugreek (Gopalan, 1971; Bijlani, 1974; Kochhar, 1996). Occasionally, a strong coloring matter like curcumin, carotene, saffron, crocin and picrocin is present in turmeric, chillies and saffron, while tamarind has tartaric acid, kokam hydroxyl citric acid, mangopowder malic acid, pomegranate seeds oxalic acid, and caper buds rutic acid (Gopalan, 1971; Bijlani, 1974; Kochhar, 1996).

On the other hand, spices contains a diverse array of natural phytochemicals that have complementary and overlapping actions, including antioxidant effects, modulation of detoxification enzymes, stimulation of immune system, reduction of inflammation, modulation of steroid metabolism and antibacterial and antiviral effects (Kochhar, 2008). Interestingly, the inherent value of phytochemicals as well as their potential toxicity to human health has also been recognized (CSIA, 1976; Cox, 1994).

A wide variety of phenolic compounds and flavonoids present in spices possess potent antimicrobial (Russel and Gold, 1991; Davidson and Baren, 1993; Deis, 1999; Sherman and Hash, 2001), antioxidant, antimutagenic and anticarcinogenic (Surh et al., 1995; Surh et al, 2000; Kandeswami et al., 2003; Sinha et al., 2003; Murakami and Ohigashi, 2007; Wang et al., 2007) activities. On the antimicrobial potentials of spices, Sagdic (2003) stated that the main factors determining the antimicrobial activity are the type and composition of the spice, amount used, type of microorganism, composition of the food, pH value, temperature of the environment, and proteins, lipids, salts, and phenolic substances present in the food environment.

It has also been deduced that one of the underlying major mechanisms is their action on cellular enzymatic pathways. Effect of aqueous extracts of turmeric, cloves, pepper, chilli, cinnamon, onion and also their respective active principles, curcumin, eugenol, piperine, capsaicin, cinnamaldehyde, quercetin and allyl sulfide were tested on human polymorphonuclear leukocyte 5-lipoxygenase (PMNL 5-LO) activity and observed that the formation of leukotrienes was significantly inhibited in a concentration-dependent manner (Prasad et al., 2004).

DISCUSSION

It is quite clear that for centuries, the inherent values and potential toxicity of phytochemicals on human health as well as the need to investigate the chief, supplementary, complementary and synergistic actions of herbs and spices in health and diseases have been recognized (CSIA, 1976; Gotlieb, 1982; Havsteen, 1983; Cox, 1994; Lampe, 2003; Szallasi, 2005; Aggarwal et al, 2007). It has been stated also, that despite the documented uses of herbs, condiments and spices, many of them need to pass the tests of modern, controlled, clinical experimentation (Hameed, 1982; Pruthi, 1987). In fact, several empirical and experimental observations have suggested that the effects of spices extend beyond taste and flavour (Murphy et al., 1978; Achinewhu, 1995; Kochhar, 1999). Even Kochhar (2008) had stated that dietary spices influence various body systems such as the gastrointestinal, cardiovascular, reproductive and nervous systems; resulting in diverse metabolic and physiologic actions.

Considering the inherent chemical properties/potentials of all the active principles in *Yaji*, it won't be out of place to say that *Yaji* is indeed chemically complex. Available literature does show that some of the active principles in *Yaji* like capsaicin, piperine and monosodium glutamate, have excitotoxic, apoptotic and tumorigenic potentials (Choi, 1988; Olney, 1989; Whetsell and Shapira, 1993; Lipton and Rosenberg, 1994; Blaylock, 1997; Olney et al., 1997; Sugimoto et al., 1998; Ankarcona et al., 1998; Martin et al., 2000; Rothstein and Brem, 2001; Bellamy, 2008). In one of our studies, we postulated that the contents in *Yaji* can induce cerebellar cell damage (Nwaopara et al., 2011) based on an earlier suggestion by Eweka and Om'Iniabohs (2007) that MSG consumption may have some deleterious effects on the cerebellum of adult wister rats at higher doses and by extension may affect the functions of the cerebellum thereby resulting in tremor, unstable and uncoordinated movement or ataxia. Their assertion was predicated upon the fact that monosodium glutamate may act as a toxin to cerebellar neurons; affect cerebellar cellular integrity; and cause defects in membrane permeability and cell volume homeostasis.

For sure, the excitotoxic potential of MSG is no longer in doubt (Espinar *et al.*, 2000; Rothstein and Brem, 2001; Urena-Guerrero *et al.*, 2003) and there is evidence too that capsaicin administration causes degeneration of neurons (Ritter and Dinh, 1993; Wood, 1993; Chard *et al.*, 1995; Jancso *et al.*, 1997). The cytotoxic potentials of piperine in black pepper have been identified and this is enhanced by the presence of tocopherol, suggesting a mechanism of lipid peroxidation (Unchern *et al.*, 1998). It has also been stated that piperine promotes DNA damage (Pychaturawat *et al.*, 1995), which is itself, a significant trigger for apoptosis.

In another study on *Yaji* in which cerebral vascular fatty infiltration was observed (Nwaopara *et al.*, 2010b), we argued that the results implicated the MSG in *Yaji*, as there are reports that MSG increases serum total proteins, cholesterol and blood glucose levels in mice (Osfor *et al.*, 1997) and in rats (Betran *et al.*, 1992). It has also been reported that MSG treated animals have increased triacylglycerol levels (Diniz *et al.*, 2005), lipoperoxidation and alteration in markers of oxidative stress lipoperoxidation (Jiang *et al.*, 1991). Existing facts show that in more than 90% of cases, fat embolism is associated with accidental trauma to long bones or pelvis, or during surgical trauma and in up to 5% of the cases, atraumatic causes like bone marrow transplantation, pancreatitis, sickle cell disease, burns, prolonged high-dose corticosteroid therapy and diabetes mellitus might be responsible, while other rare causes include hepatic trauma, liposuction, lipectomy, external cardiac compression, gas gangrene, decompression sickness and lipid infusions (Levy, 1990; Dudney and Elliott, 1994). The inclusion of pancreatitis and hepatic trauma in the list of causes of fat embolism correlated with previous histological findings that *Yaji* can induce pancreatic and liver damage in experimental rats (Nwaopara *et al.*, 2004; 2007).

Findings from the same study (Nwaopara *et al.*, 2010b), implicated the groundnut cake powder in *Yaji* because there are reports that dietary oil rich in polyunsaturated fatty acids is susceptible to oxidative changes during use like frying (Ologan, 2002). The reason is that the polyunsaturated fatty acid constituents of these oils readily undergo oxidation resulting in the formation of peroxides, aldehydes, ketones, aldehydoesters and ozonides (Frankel, 1980; Kubow, 1992, Odotuga *et al.*, 1997). The consumption of such peroxidized lipids has been shown to be injurious to health (Frankel, 1980; Halliwell and Gutteridge, 1984; Addis, 1986; Kubow, 1992). In one report, Jimoh and Odotuga (2002) revealed that oxidised groundnut oil can induce the disintegration of alveoli membrane and collapse of alveoli spaces in the lungs (signifying an impairment in the oxygenation of blood) as well as a disorganization of the spatial arrangement of the cells and widening of the fibres of the heart, which might lead to weakness of the cardiac muscle and consequently, cardiac enlargement and cardiac failure. Of course, these conditions can induce cerebral hypoxia and ischaemia respectively.

Furthermore, a comparison between the findings of the study by Nwaopara *et al.* (2010b) and existing scientific data on excessive salt intake was made and this revealed that the salt in *Yaji* is a likely 'suspect' as autopsy reports on cases of fatal sodium chloride poisoning have shown that brain edema, venous and capillary congestion, cortical venous thromboses and venous brain infarcts are more predominant (Kosti-banovi. *et al.*, 2005). Several other scientific reports have also implicated hypernatremia in brain cells dehydration, brain volume decrease, mechanical damage of small blood vessels and subarachnoid and intra-cerebral hemorrhages (Young and Truax, 1979; Palevsky *et al.*, 1996; Michael and Jocelyn, 1997; Mocharla *et al.*, 1997). Hypernatremia occurs when there is a deficiency of water in the body compared to solute sodium chloride ions (Kosti-banovi. *et al.*, 2005). This state can occur as a consequence of insufficient liquid intake or its extreme loss or increased exogenous sodium chloride intake (Stefanovic., 1994; Michael and Jocelyn, 1997; Adroque and Madias, 2000).

In addition, findings on the tumorigenicity of *Yaji* (Nwaopara *et al.*, 2009b) implicated the active principles in *Yaji*, as there is evidence that MSG is tumourigenic (Rothstein and Brem, 2001; Bellamy, 2004). There is evidence also, that excitotoxic destruction facilitates brain tumor growth. This by implication, indicate that the combined influence of all the excitotoxic elements in *Yaji* such as MSG, capsaicin and piperine is one factor that might as well account for the observed tumour formation. Of course, the excitotoxicity of MSG is well known (Espinar *et al.*, 2000; Rothstein and Brem, 2001; Urena-Guerrero *et al.*, 2003) and capsaicin administration causes degeneration of neurons (Jansco *et al.*, 1977; Ritter and Dinh, 1993; Wood, 1993; Chard *et al.*, 1995). Piperine also, is said to be cytotoxic (Unchen *et al.*, 1998) as it promotes DNA damage (Pychaturawat *et al.*, 1995), which is itself, a significant trigger for apoptosis.

Available literature shows that less than one percent of cancer deaths in industrialized nations are attributable to food additives and industrial products (Trichopoulos and Li, 1996). Dietary factor has also been estimated to account for about one third of cancer deaths in the United States (Doll and Peto 1981; Ames *et al.*, 1995; American Cancer Society, 2000; Ries *et al.*, 2000). Also, there is a report associating cancers of the breast, oral cavity

(primarily in smokers), and liver with an excessive consumption of alcoholic beverages (International Agency for Research on Cancer, 1988; Willett, 2001). The import of this is that at high doses, *Yaji* is capable of inducing brain tissue damage as well as tumour formation in a manner that is likely dependent upon the concentration of those ingredients with excitotoxic and tumorigenic potentials in a given measure of *Yaji*.

Recent findings on hematological parameters (Akpamu et al., 2011a; b), suggests also that *Yaji*, *Yaji*-spices and *Yaji*-additives have the capacity to induce dosage and duration dependent alterations. Thus, the researchers concluded that the observed results further indicate that an unregulated consumption of *Yaji*, has its implications on the health of consumers considering the clinical significance of the hematological parameters in question particularly PCV (Akpamu et al., 2011a; b).

From the foregoing therefore, it is apparent that the observed potentials of *Yaji* are most likely dependent upon the combined effects of its active ingredients. The highlighted effects indicate that an unregulated production and consumption of *Yaji* is capable of inducing tissue damage and such damage may be the bases for secondary outcomes. The findings suggests also that the most significant factor is apparently the quantity of harmful elements within a given measure of *Yaji* as the tissue damages become magnified with increases in dosage and duration.

CONCLUSION

The chemical composition of *Yaji* is indeed complex and judging by the facts available, one might conclude as expected, that the consumption of *Yaji* is always likely to produce a negative effect. This however, should not be the case as the challenge remains the effect of its excessive and indiscriminate consumption. Moreover, there is this conviction that a moderated consumption of *Yaji* can produce positive results in some sense, as evident in the reports by Nwaopara et al. (2009) and Akpamu et al. (2011c) on its antimicrobial and anti-obesity potentials respectively.

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AUTHORS' CONTRIBUTIONS

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