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NOVEL APPLICATION FOR FIBERMETRIC ANALYSIS - FIBER POWER OF LEAFY VEGETABLES

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ABSTRACT

The article presents a novel application for fibremetric analysis which provides a basis for the development of a dietetic index for edible, green leafy vegetables. An original idea is additionally proposed to characterize physiological responses in man, to dietary fiber ingestion. The factor developed for this purpose consists of the ratio of percent crude fiber in a leafy vegetable to an L/W factor. This latter is the ratio of the length to width of individual fiber strands, isolated from the leafy vegetables.

Six green leafy vegetables native to Nigeria were studied. Results revealed fibers of significantly ($p<0.01$) characteristic sizes. These correlated positively with their crude fiber estimates as well as with known physiological responses in man, to their ingestion.

Fiber dimensions did not however correlate significantly with quantitative measures of available carbohydrate. Results are discussed in terms of the proposed dietetic index and its proposed role in nutrition, diet and health.

KEYWORDS:

Dietary fiber; fibermetrics; leafy vegetables; laxation; constipation; atherosclerosis; dietetics.

INTRODUCTION

Fibermetry has found application in the pulp and paper industry where fiber dimensions of woody trees play crucial roles in the determination of both type and quality of paper manufactured (Ademiluyi and Okeke, 1972; Casey, 1960). In the world of nutrition and dietetics however, there has been no precise nor concensused measure for the quantitation or characterization of dietary fibers (Hillemeier, 1995; Nicklas *et al* 1989), nor has there been any such assay that measures the degree of its physiological effect(s) on the human system. How much of these fibers and which types, elicit physiological response(s) and to what extent?

The vegetables studied in this paper are those native to the peoples of Akwa Ibom State in Nigeria (5 4N, 7 59E). They were carefully selected because some of these vegetables are becoming relatively less popular due to deforestation and urbanization. Many of them are however very important to the rural populace since they have known medicinal, nutritional and culinary benefits (Table 1) as handed down in oral history to traditional herbalists.

Two major dietary fiber types have emerged over the years, evolving from what used to be known as crude fiber content of foods. They are the soluble and non-soluble fibers (Kwiterovich, 1995). The former, i.e. soluble fibers (SF), have a more diverse physiological role. They are found in fruits, vegetables and grains (Kimm, 1995), are usually viscous, contain tocotrienols

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and are hypocholesterolemic (Nicklas *et al*, 1989; 1995; Kwiterovich 1995). They also bind carcinogens and other noxious substances (Williams and Bollela, 1995). SF however, contain many antinutrients such as saponins, tannins, haemagglutinins, phytates and oxalates (Agostoni *et al*,, 1995) that are responsible for micronutrient chelation and their subsequent fecal losses and/or delayed absorptions (Williams and Bollela, 1995). The latter fiber type are termed insoluble fibers (ISF) and are sometimes also referred to as non-soluble polysaccharides (NSP). These are extracted as sheer fibers (or their enzyme-digested fragments) and are responsible for fecal bulk (Kwiterovich, 1995; Williams and Bollela, 1995). They compromise caloric and proteic densities because they take a longer time to chew and cause quicker attainment of satiety due to their bulk (Kimm, 1995; William and Bollela, 1995). However, they are partially or slowly fermented by gastrointestinal tract (GIT) flora to yield acetic, propionic and butyric acids which may increase caloric intake by an average 7% (Agostoni *et al*, 1995). ISF provide the surface area for GIT microflora proliferation and thus the more complete fermentation of SF (Hillemeier, 1995). This however produces gases and concommittant GIT discomfort (Williams and Bollela 1995). Both SF and ISF are normally resistant to human digestive enzymes but may be digested by GIT microflora (Hillemeier, 1995). Because of the sheer bulk of ISF, they delay absorption and bioavailability of proteins and micronutrients like Fe, Ca, Zn, Cu, Mg, P and riboflavin (Williams and Bollela, 1995).

There is increasing concern about the need for better, more adequate and universally acceptable methods for the assay of dietary fibers (Hillemeier, 1995; Stewart, 1994; Nicklas *et al*, 1989). This paper presents data on the fibermetric analysis of six, edible, green leafy vegetables native to Nigeria. One of the analytical parameters used is the crude fiber estimate. The use of this parameter is discouraged in the industrialized world (Hillemeier, 1995) due to the emergence of better defined fiber groups as well as because of improved methods of chemical analysis. However, in developing nations such as Nigeria where modern, sophisticated equipment are unavailable, the crude fiber assay still has its usefulnesses, especially in a study like this one in which emphasis is placed more on comparisons than on absoluteness. An equivalent parameter in the comtemporary science world would probably be the sum of both SF and ISF estimates.

Other fibermetric parameters employed in this study included the length and width of individual fibers which is currently measured in the paper industry by use of the automated Kelani fiberlyser. In this instance once again, a less sophisticated but easily accessible method (TAPPI 1980) was employed for the same reasons as described earlier.

This paper additionally proposes an L/W factor (ratio of length to width of individual fiber strands) which has been developed by the authors for the determination of a suggested "fiber power" entity for dietary vegetables. This may assist in characterizing some physiological responses to the ingestion of such dietary fibers. The proposal is still in its preliminary stage and may raise certain questions which are addressed in the text. It is hoped that the proposal will generate sufficient integrity to warrant testing by other researchers.

MATERIALS AND METHODS

Six, mature, green leafy vegetables, one of which had two varieties, were used. These were freshly harvested in May from varying backyard gardens in Uruan Local Government Area of Akwa Ibom state, Nigeria. Leaves were removed from their stems, destalked,

TABLE I: Traditional Uses of Some Vegetables Eaten in Akwa Ibom State, Nigeria.

SAMPLES	CULINARY	MEDICINAL
Gnetum africanum	Soups, Salads (filling)	Strong laxative
Lesianthera africana	Bitter flavored soups (filling)	Purgative/GIT disorders
Heinsia crinita (white variety)	Aromatic, bitter flavored soups	Enema, diarrhea
Heinsia crinita (black variety)	Aromatic, bitter flavored soups	Purgative, abortifacient, pustulation, peptic ulcer
Piper guineense	Pepperic spice, light aromatic soups	Enema
Portulaca oleracea	Spinach, salad, very light soups, pickles	Mild laxative for infants, anti pyretic, lung inflamations, spinal cord injury, muscle relaxant, dermatoses
Asystasia gangetica	Spinach, salad, weaning	Mild laxative for infants, wound
gangetica	Vegetable for infants, garnish for other soup	healing, antipruritic, vaginal douche.

washed and oven-dried (50°C/48 hrs). They were then blenderized using an electric blender and stored in labelled, air tight, brown bottles for use in some of the analyses.

Crude fiber content of each fat-free sample was determined by acid and base digestion, followed by weight difference on muffle furnace ignition at 500°C, of the samples (AOAC, 1984). Available carbohydrate (this does not include enzyme hydrolyzed starch) was estimated as glucose, using Anthrone reagent (Joslyn, 1970) while total reducing sugar was estimated also as glucose, using Benedict's quantitative reagent (Joslyn, 1970).

Neat, individual fibers were prepared from each sample in the following manner (TAPPI, 1980): 2g each of air-dried, destalked, fresh leaf chips (diced with a kitchen knife) were made fat-free using a soxhlet extractor (petroleum ether: methanol, v/v 1:1) for five hours. Samples were subsequently treated with a mixture of hydrogen peroxide and glacial acetic acid (v/v, 1:1) and subjected to oven heating (60°C/12-24 hrs.), at the end of which the resulting pulp was subjected to mild pulverization using a glass rod. Fibers were washed several times with distilled water. The neatly separated and bleached fibers so obtained were singly mounted on a microscope slide and fiber lengths and widths measured using a microscope with calibrated occulars (x10) and stage graticules. 30 measurements were taken for each random fiber sample and results were statistically analyzed. This method, though somewhat tedious, is well suited to the under-equipped laboratory.

RESULTS AND DISCUSSION

Fibermetric Values of the Vegetables

The application of fiber metrology to dietary fibers as opposed to pulp and paper fibers, is novel. *Gnetum africanum* leaves were observed to have the highest percentage crude fiber (16 ± 0.02% dry weight) of the six vegetables studied, followed by the two varieties of *Heinsia crinita, Lesianthera africana, Piper guineense* and finally the two very succulent leafy vegetables, *Asystasia gangetica* and *Portulaca oleracea* (Table II).

It is striking that these data precisely reflect in matching descending order, the known laxative effects of the vegetables (Ekott, 1990; Ibanga, 1990). While soups made with *G. africanum* are traditionally first choice for very bad cases of constipation in adults, the latter two, particularly *A. gangetica,* are popularly used traditionally as very mild purgatives for infants who are constipated by milk. Research shows that high fiber diets are unsuitable for infants and cause growth depression and mineral deficiencies (Dwyer, 1995). 0.5g fiber/kg body weight is the American Association of Pediatricians (AAP) recommended level for children (Dwyer, 1995).

Crude fiber values of some commonly consumed green leafy vegetables in Nigeria range between 10-13% dry matter (Odutola and Cari, 1963; Ifon and Bassir, 1979; Oyenuga, 1968). Compare with values of 4-16% dry matter obtained in this report.

A trend comparable to that discussed above was also observed for fiber lengths and widths of the vegetables (Table II) where *G. africanum* had the highest fiber length of 1.46 ± 0.011mm and width of 0.02 ± 0.013mm while *P. oleracea* had the lowest of 0.6 ± 0.013mm and 0.006 ± 0.001mm respectively for length and width. All differences were statistically significant ($P<0.01$) and indeed there was positive correlation ($r = 0.93$). between these fiber dimensions and per cent crude fiber content.

Interestingly, there was statistical difference ($P<0.01$)

TABLE 2: Crude Fiber (%) Content and Fiber Dimensions (mm) of the Vegetable leaves

SAMPLE	CRUDE FIBER	FIBER** LENGTH*	FIBER WIDTH*
Gnetum africanum	16.0 ± 0.02	1.46 ± 0.011	0.020 ± 0.001
Heinsia crinita (White variety)	15.1 ± 0.02	1.39 ± 0.018	0.014 ± 0.001
Heinsia crinita (Black variety)	15.0 ± 0.02	1.33 ± 0.022	0.013 ± 0.003
Lesianthera afriana	13.6 ± 0.01	1.18 ± 0.009	0.012 ± 0.000
Piper guineensis	11.3 ± 0.01	0.87 ± 0.011	0.009 ± 0.000
Asystasia gangetica	4.5 ± 0.01	0.80 ± 0.029	0.008 ± 0.001
Portulaca cleracea	4.2 ± 0.00	0.60 ± 0.013	0.006 ± 0.001

* Mean ± s.d of 30 random samplings. ($P<0.01$).
**Mean ± s.d. of triplicate determinations. ($P<0.01$).

TABLE III: Calculated Indices for the Vegetable Fibers+

SAMPLES	L/W FACTOR*	FIBRE CONTENT PER L/W FACTOR** (%)	FIBRE CONTENT Per Unit Fibre (%/mm)***
Gnetum africanum	73	0.220	10.96
Heinsia crinita (White variety)	93.3	0.150	10.86
Heinsia crinita (Black variety)	102.3	0.146	11.28
Lesianthera africana	98.3	0.138	11.53
Piper guineense	96.6	0.113	12.99
Asystasia gangetica	100	0.045	5.63
Portulaca oleracea	100	0.042	7.00

+The vegetable samples are listed in descending order of magnitude in percent crude fiber, fiber length and fiber width.
This is representative of the true trend.

*The L/W factor does not conform with the true trend. It is a partial index.
*The fiber content per L/W factor otherwise termed "fiber power" conforms with the true trend and is a more total index than any of the other parameters.
***The fiber content per unit fiber is only a partial index and thus does not conform with true trends.

between the fiber dimensions of leaf fibers in the two varieties of *H. crinita* (Table II). A further observation from obtained data is that leafy fibers of *G. africanum* are biggest (both longest and widest) while those of *H. crinita* are long but slim.

Fiber power - a proposal

Length/width ratios (the authors choose to term this as L/W factors) were calculated for all samples. Not unexpectedly, these ratios modified the previously observed orders (Table III) to *G. africanum* > *P. guineensis* > *L. africanum* > *H. crinita (white)* > *A. gangetica* > *P. oleracea* > *H. crinita (black)*. It would thus appear that the L/W factors may not accurately reflect the true physiological roles of the dietary fibers vis-a-vis laxation, as earlier established. Similarly, the percent crude fiber per unit fiber length did not reflect these true trends either (Table III).

The authors choose to term this fiber function as "fiber power". They deduced that the so-termed fiber power of a leafy vegetable could more completely be depicted not only by the fiber dimensions of the leaves but by their fiber quantity as well.

The entity, "fiber power", was therefore developed and calculated as the ratio of per cent crude fiber in the leaf relative to its L/W factor. These calculated values from the results shown in Table III, did appear to be more aptly representative of the true trend as previously established. Fiber power may therefore be defined as the fiber quantity of a leafy vegetable in relation to its linear fiber quality or dimensions. The authors are of the opinion that it should represent the total magnitude of all the biological responses the fiber can elicit -mechanical, biochemical and physiological. For instance, the fiber power of a leafy vegetable should certainly influence the extent of normal and corrective laxation in humans. The fact that observations made in this study as establishing trends, neatly conform with those already articulated by native herbalists, lends come credence to this. There was no significant correlation between fiber dimensions and total available carbohydrate and reducing sugar (Table IV) and so these parameters were not considered relevant to the calculated factors above.

There is need for a single or small number of characteristics that would embody the physiological responses to ingestion of different fibers and thus allow their categorization. However, considerably more work has to be done with the proposed "fiber power" factor. First there is room for improvement in methodology. The crude fiber value for a food is poorly related to contemporary definitions of dietary fiber and can be improved upon possibly by replacing the crude fiber estimates with one that embraces the sum total of soluble and insoluble fibers.

The classification of dietary fiber based on solubility is in itself loose and arbitrary (Hillemeier 1995). However, the fiber dimensions measured in this study are based on linearity of fiber strands and it would appear that the ISF seem relatively more critical for these factors calculations. This may therefore be adequate for dietary fibers of leafy vegetables where ISF to SF ratios are high. In fruits and grains where such ratios should be lower, the efficacy of linear measurements becomes problematic unless viewed relative to ISF/SF ratios. It may well turn out that higher ISF/SF ratios, depicting that leafy vegetables with high fiber power such as *G. africanum* could be more dietetically useful in laxation treatments while those with just moderate power such as *L. africana* could find more prophylactic application if used as regular inclusions in diets of atherosclerotic, diabetic and cancer patients. Those with low fiber power such as *A. gangetica* may best be suited for health maintenance in infants. This theoretical factor requires further elucidation through collaborative scientific efforts.

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