American Journal of Biological Chemistry
2019; 7(2): 38-46
http://www.openscienceonline.com/journal/ajbc

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Socio-economic Value, Chemical Composition, Biological Activities and Nutritional Value of Noni (*Morinda spp*): A Review

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To cite this article

Jimoh Kazeem Akanni, Lawal Ibraheem Oduola, Gbolagade Olatoke Teslimah, David Esther Olufunmilayo. Socio-economic Value, Chemical Composition, Biological Activities and Nutritional Value of Noni (*Morinda spp*): A Review. *American Journal of Biological Chemistry.* Vol. 7, No. 2, 2019, pp. 38-46.

Received: February 26, 2019; **Accepted**: April 3, 2019; **Published**: April 26, 2019

Abstract

Morinda spp (Noni), a plant originally from Southeast Asia, is a valuable source of natural products for its socio-economic, chemical and biological benefits to mankind. This review was carried out to reveal its nutritional and therapeutic value, as well as a number of socio-economic benefits. Several findings showed that *Morinda spp* contributes to a country's economy through the production of fruit drinks from the plant and its related products which is a multimillion dollar industry. The biggest commercial value of its fruit is in beverages, fruit powders, toiletries, and oil. Their biggest markets consist of Asia, Australia, and North America, and the largest producer is Hawaii. The worldwide market for these fruits moves an estimated $400 million USD annually. The use of *M. citrifolia* has recently grown tremendously in North America, Western Europe and elsewhere and it is now widely available in health food stores, pharmacies, grocery stores and through the Internet. It is cultivated for commercial use in the Pacific islands, particularly in Tahiti and Hawaii, as well as Australia, and, more recently, Florida. Morinda plant rise in popularity as a dietary supplement is most likely due to the increase in its publicity and marketing as a general cure-all or panacea for a number of chronic conditions. This review highlighted the socioeconomic value, chemical composition and the different biological effects of Morinda, which are anti-oxidant, antibacterial, anti-cancer, antifungal, anti-hepatoprotective, antiviral, anti-microbial, anti-obesity and hypoglycemic, anti-helmintic and analgesic effects. Market interest in this fruit suggests a bright future, although more studies are needed in areas of its profitability and market analysis to determine the economic potential of this plant.

Keywords

Morinda spp, Noni, Socio-economic Value, Biological Effect, Chemical Composition

1. Introduction

There is a spontaneous rise in population which results in pressure and fast depletion of natural resources. In order to meet various human needs, attention should be paid on diversification of the present day agriculture. Medicinal plants and herbs are of great importance to the health of individuals and a scientific investigation of traditional herbal remedies for metabolic disorders may provide valuable lead for the development of alternative drug and therapeutic strategies. For a long period of time, plants have been a valuable source of natural products for maintaining human health, especially in the last decade, with more intensive studies for natural therapies. Now a day, the use of phytochemical for pharmaceutical purpose has gradually increased in many countries. According to World Health Organization (WHO) medicinal plants would be the best source to obtain a variety of drugs. About 80% of individuals from developed countries use traditional medicine, which has

compounds derived from medicinal plants [33]. The antimicrobial compounds produced by plants are active against plants and human pathogenic microorganism. Medicinal plants represent a rich source of antimicrobial agents. Plants are used medicinally in different countries and are a source of many potent and powerful drugs. Infectious diseases caused by number of microorganisms are the world's major threat to human health and account for almost 50,000 deaths every day [14]. *Morinda spp* is a plant that possesses all of these properties.

Morinda is a genus of flowering plants in the madder family, Rubiaceae in the major group *Angiosperms* (Flowering plants). The generic name is derived from the Latin words *morus* "mulberry", from the appearance of the fruits, and *indica*, meaning "of India" It comprises approximately 80 species, distributed in all tropical regions of the world. These species may be trees, shrubs or vines; some, like *Morinda citrifolia*, are trees that very much resemble vines. All *Morinda* species bear aggregate or multiple fruitsthat can be fleshy (like with *Morinda citrifolia*) or dry. Most species of this genus originate in the area of Borneo, New Guinea, Northern Australia, and New Caledonia. Morinda is used as a herb in Traditional Japanese, Korean and Chinese Medicine. Morinda species can be utilized for the good source of nutrients and supplements. *Morinda spp* are commonly well known for the excellent source of nutrients such as minerals and vitamins; and also contain antimicrobial, anticancer, antibacterial, anti-tubercular and wound healing properties. The fruits, seeds and leaves of many of these species already form common ingredients in a variety of traditional native dishesas they serve as a vital portion of an adequate diet, as food supplement, and an appetizer for the rural populace in developing countries. Among the many species comprising this genus, six are of some pharmaceutical and technical importance; *Morinda pubescens*, *Morinda citrifolia*, *Morinda lucida*, *Morinda royoc, Morinda officinalis*, *Morinda panamens* i. Therefore, this study was designed to review the socio-economic value, nutritional and therapeutic value of *Morinda spp.*

1.1. Plant Description

The genus *Morinda* (Rubiaceae) is made up of around 80 species. *Morinda spp* is a bush or small tree, 3–10m tall, with abundant wide elliptical leaves (5–17cm length, 10–40cm width). The small tubular white flowers are grouped together and inserted on the peduncle. The petioles leave ring-like marks on the stalks and the corolla is greenish- white ([33, 16, 13]). The fruit is oval and fleshy with an embossed appearance but varies in sizes. It is slightly wrinkly, semi-translucent, and ranges in colour from green to yellow, to almost white at the time of picking. It is covered with small reddish-brown buds containing the seeds. The ripe fruit exhales a strong butyric acid-like rancid smell ([33, 13]). The pulp is juicy, bitter or depending on the specie, light dull yellow or whitish, gelatinous when the fruit is ripe; numerous hard triangular reddish-brown pits are found, each containing four seeds (3.5mm) [14].

1.2. Yields

Morinda spp is a perennial bush, generally found from sea level to 400m altitude, and it is possible to find fruits at different stages of maturity on the same plant at the same time. Under favorable conditions, the plant bears fruit about nine months to one year after planting. At this stage, the fruits can be harvested, but they are generally small and the yield per tree is low. Some producers choose not to harvest in the first year, and they prune in order to let the bush grow stronger. In Hawaii, *Morinda citrifolia* fruits are harvested throughout the year, although there are seasonal patterns in flowering and fruit bearing (meteorological factors, fumigation, and irrigation) ([35, 36]). Noni plots are usually harvested two or three times per month, although fruit production is lower during winter. With a density of 638 plants per hectare with good soil fertility, drainage, and irrigation and appropriate pest, disease and weed control, along with an appropriate fertilization plan, it is possible to obtain yields of between 7tonnes/ha/year in the second year after planting to approximately 70tonnes/ha/year after the fifth year ([35, 36]). Depending on the post-harvest technology programme adopted, the fruits may be harvested at different stages of development and continue to mature.

2. Socio-economic Value of Morinda Plant

Wild resources, from several studies, form an integral part of livelihoodwild resources. Wild resources provide materials for utensils and construction, contribute to improved diets and health, food security, income generation, and are used for genetic experimentation. These resources are typically associated with hunting and gathering societies where they often have special cultural significance, but they also play important roles more intensive or specialized agricultural systems. The socio-economic value of biological diversity resides not only in the direct use that one makes of biological resources, but also in the indirect uses, such as the ecological services (e.g. improvement of the quality of water and air, the fixing of nitrogen, the formation of soils), socio-cultural uses (e.g. religious and cultural functions), recreational and aesthetic uses (e.g. tourism of vision), etc. These uses end up at the level of feeding and the different sectors of activity that are interested in biological diversity.

Morinda spp is a plant originally from Southeast Asia, where it has been used as part of culinary lore for hundreds of years. Nowadays, numerous people are familiar with morinda fruits as part of mixed fruit drinks, although there is still much to learn about its immense nutritional and medicinal prestige. *Morindacitrifolia* fruit juice have additional uses. It is often kept as an ornamental plant, and the fruit's seeds are a popular bird feed. The trunk of the *M. tinctoria*, *M. pubescens* and *M. citrifolia* is used for firewood, and the bark and roots are often used as pigment for red and

yellow dyes. *Morindalucida* can also be used as an effective insect repellant. For over 2,000 years, M. citrifolia fruit has been an important food source across different Pacific islands. The early French Polynesians consumed it in times of famine, while people in Burma cooked the ripe fruits with salt. Australians aborigines were also found of this fruit, and they were the first to apply its medicinal properties. On the Asian continent, the seeds, leaves, bark, and roots of the fruit were also eaten in India, Burma, and the Philippines. In most industrialized societies, juices containing *M. citrifolia* fruit are available year-round in major food markets or health stores. Although it is overwhelmingly more available as juice, several other forms are also available. Both raw *M. citrifolia* fruit juice can be found in most large grocery stores and markets around the world. The most common presentation of raw *M. panamesis* drink is the leaves, which can then be boiled in water to make a hot beverage. Mixed fruit juices containing *M. panamensis* fruit are also widely available. In addition, there is a wide variety of its supplement choices available through online retailers. Each brand of supplement may come with different concentrations, dosages, or presentations. Although extracts or seed oils are overwhelmingly more accessible, capsules can also be found and purchased.

Nowadays, the production of fruit drinks from *Morinda spp* and its related products are a multimillion dollar industry. The biggest commercial value of its fruit is in beverages, fruit powders, toiletries, and oil. Their biggest markets consist of Asia, Australia, and North America, and the largest producer is Hawaii. The worldwide market for these fruits moves an estimated $400 million USD annually.

3. Chemical Composition of *Morinda spp*

About 160 phytochemical compounds have been already identified in morinda plant, and the major micronutrients are phenolic compounds, organic acids and alkaloids [51]. Of the phenolic compounds, the most important reported are anthraquinones (damnacanthal, morindone, morindin, etc.) and also aucubin, asperuloside, and scopoletin (Table 1) [51]. The main organic acids are caproic and caprylic acids [14], while the principal reported alkaloid is xeronine [21]. However, chemical composition differs largely according to the part of the plant. The complete physicochemical composition of the fruit has not yet been reported and only partial information is available on *M. citrifolia* fruit juice. The fruit contains 90% of water and the main components of the dry matter appear to be soluble solids, dietary fibers and proteins [11]. The fruit protein content is surprisingly high, representing 11.3% of the juice dry matter, and the main amino acids are aspartic acid, glutamic acid and isoleucine [11]. In *Morinda royoc,* minerals account for 8.4% of the dry matter, and are mainly potassium, sulfur, calcium and phosphorus; traces of selenium have been reported in its juice [11]. Vitamins have been reported in its fruit, mainly ascorbic acid (24–158mg/100g dry matter) ([33, 44]), and pro-vitamin A [13]. Phenolic compounds have been found to be the major group of functional micronutrients in *M. tinctoria* fruit juice, which are damnacanthal, scopoletin, morindone, alizarin, aucubin, nordam- nacanthal, rubiadinand rubiadin-1-methyl ether. Other anthraquinone glycosides have been identified in its juice ([33, 14, 13, 51]). Damnacanthal is an anthraquinone that has been characterized recently and has some important functional properties (mainly anti-carcinogenic) [45]. Scopoletin is a coumarin that was isolated in 1993 at the University of Hawaii and has been found to have analgesic properties as well as a significant ability to control serotonin levels in the body. Other researchers have shown that scopoletin may also have anti-microbial [15] and anti-hypertensive effects [45]. Different Hawaiian teams reported the presence of a novel component, Proxeronine, in the *M. citrifolia* ([21, 45]). It would be the precursor of xeronine, an alkaloid that is claimed to combine with human proteins, improving their functionality. These authors attribute most of all the beneficial effects of noni to xeronine. Nonetheless, neither the chemical characterization of this alkaloid has been published nor the method used to assess its content. About 51 volatile compounds have been identified in the ripe fruit of *M. citrfolia* [41], including organic acids (mainly octanoic and hexanoic acids), alcohols (3-methyl- 3-buten-1-ol), esters (methyl octanoate, methyl decanoate), ketones (2-heptanone), and lactones[(E) -6-dodeceno-g- lactone] [19].

4. Nutritional Value of Morinda Plant

The *M. citrifolia* fruit contains 90% of water and the main components of the dry matter appear to be soluble solids, dietary fibres and proteins. The fruit protein content is surprisingly high, representing 11.3% of the juice dry matter, and the main amino acids are aspartic acid, glutamic acid and isoleucine [11]. *Morindatinctoria* plantminerals content account for 8.4% of the dry matter, and are mainly potassium, sulfur, calcium, phosphorus and traces of selenium have been reported in the juice [11]. Recently, the polysaccharide content of the *M. royoc* has been investigated using monosaccharide and glycosyl linkage analysis. The most abundant monosaccharides found were arabinose (Araf), galactose (Galp), galacturonic acid (GalAp) and rhamnose (Rhap) [8]. The vitamins reported in the *M. pubescens* fruits are mainly ascorbic acid (24 to 158 mg/100 g dry matter) ([33, 44]) and provitamin A [13]. The major components identified in *Morinda tinctoria* plant include octoanic acid, potassium, vitamin C, terpenoids, scopoletin, flavones glycosides, lineoleic acid, anthraquinones, morindone, rubiadin, and alizarin. The fibre content is low in *M. citrifolia* and high in *M. pubescens* fruits. It also indicates that the pulp contained a considerable amount of sugar while the sugar content of the *M. pubescens* was lower than *M. citrifolia*. The use of *M. citrifolia* has recently grown tremendously in North America, Western Europe and elsewhere and it is now widely available in health food stores, pharmacies, grocery stores

and through the Internet. It is cultivated for commercial use in the Pacific islands, particularly in Tahiti and Hawaii, as well as Australia, and, more recently, Florida. Morinda plant rise in popularity as a dietary supplement is most likely due to the increase in its publicity and marketing as a general cure-all or panacea for a number of chronic conditions ([45, 16]).

5. Biological Activities of *Morinda spp*

One can easily find out several research articles on the biological activities and pharmacological actions of *Morinda spp* based on modern scientific investigation.

Table 1. *Biological and pharmacological actions of different Morinda species.*

Species	*Compound*	Activities
Morinda citrifolia	*Octanoic acid*	Antifungal, antioxidant
	Ursolic acid	Anticancer
	Americanin A	Antioxidant
	Leucine, glycine, Arginine, histidine	A source of essential amino acids.
	Quercetin-3-O-B-D-glucopyranoside	Antimicrobial Lowering blood cholesterol
	B-sitosterol	Suppressing UVB-induced activator protein-1 activity
	Citrifolinoside	Anti-proliferative effects on cancer
	Scopoletin	Nutritional & antioxidant
	Vitamin C, E	Nutritional
	Manganese	Antiviral
	Anthraquinone	Antioxidant
	Coumarin	Anti-hepatoprotective
Morinda pubescens	*Alkaloid*	Antimicrobial
	phenols	Source of essential and conditional amino acids
	Glycosides	Antifungal
	Protein	Antibacterial
	Fluconazole	Analgesic
	Ofloxacin	Antibacterial
	Morphine	Antimicrobial
	Anthraquinones	Anticancer
Morinda royoc	*Oxacillin*	Antihypoglycemic
	Ursolic acid	Antifungal
	Lucidin	Antipyretic
	Fluconazole	Nutritional
	Flavoniods	Source of essential amino acid
	Manganese	Anticancer
Morinda angustifolia	*Glutamic acid, Serine*	Antifungal
	Damnacanthal	Antidiabetic
	Caproic acid	Nutritional
	Insulin	Antibacterial
	Niacin	Analgesic
Morinda tinctoria	*Iridoid*	Analgesic activity
	Morphine	Antipyretics
	Morphine	Antimicrobial
	Flavonoids	Antidiabetics
	Glycosides	Antibacterial
Morinda lucida	*Steroids*	Antioxidant
	Anthraquinones	
	Alkaloids	

5.1. Anti-oxidant Properties

Degenerative human diseases have been recognized as being a consequence of free radical damage. Studies have shown that high consumption of fruits and vegetables containing phenolic antioxidants, inhibit the oxidation of low density lipoprotein (LDL), thus slow the process of atherosclerosis and also reduce the risk of cancer and many other diseases. It is encouraging to see that all the chromatographic fractions obtained from the root, fruit and leaf demonstrated high antioxidative activity when compared with either butylatedhydroxytoluene (BHT) or α-tocopherol [31]. The anti-oxidant properties of ethanol and ethyl acetate extracts of *Morindaroyoc* bark have been assessed using the ferric thiocyanate method (FTC) and thiobarbituric acid test (TBA). The authors found that ethyl acetate extract exhibited strong inhibition of lipid oxidation comparable to the same weight of pure a-tocopherol and butylatedhydroxy toluene (BHT) [31]. Radical scavenging activity was also measured in vitro by the tetrazoliumnitroblue (TNB) assay on a commercial juice, by assessing the potential capacity of the juice to protect cells or lipids from oxidative alteration promoted by superoxide anion radicals (SAR). The SAR scavenging activity of noni juice was shown to be 2.8 times higher than that of vitamin C, 1.4 times that of pycnogenol (PYC) and almost of the same order as that of grape seed powder [51]. Studies also suggested that diabetic animals exposed to oxidative stress and *Morindatinctoria* (MTR) can partially reduce the imbalances between the generation of reactive oxygen species (ROS) and the scavenging enzyme activity. According to these results, *M. tinctoria* (MTR) could be a supplement, as an antioxidant therapy, and may be beneficial for correcting the hyperglycaemia and preventing diabetic complications due to lipid peroxidation and free radicals. The *M. tinctoria* (MTR) fruit is not only similar to insulin in having a hypoglycaemic effect; it also controls the antioxidant level and could be used to improve the lipid metabolism. Longer duration studies of *Morindatinctoria* (MTR) and its isolated compounds on chronic models are necessary to develop a potent Anti-diabetic drug.

5.2. Antibacterial Activity

The antibacterial activity of *M. citrifolia* against certain infectious bacterial strains (such as Pseudomonas aeruginosa, Proteus morgaii, Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Salmonella and Shigella), as reported by [5], was deduced that the anti- microbial effect observed may be due to the presence of phenolic compounds, such as acubin, L-asperuloside, and alizarin in the fruit, as well as some other anthraquinone compounds in roots. Also antimicrobial effect was observed on different strains of Salmonella, Shigella, and E. coli ([5] [9, 14]). It was revealed that *Morindaroyoc* showed a greater effect against oxacillin-resistant Staphylococcus aureus (ORSA) strain than either oxacillin or cephalotin, but this bacterium was susceptible to vancomycin. The Gram-negative microorganisms: Acinetobacterbaumanii, Pseudomonas aeruginosa, and

Klebsiellapneumoniae, were resistant to the extract, anthraquinones, and controls. Only the Gram-negative bacterium Escherichia coli was susceptible to either cephalotinoroxacillin. From the anthraquinones assayed, only morindone was active against ORSA strain. Although the anti-bacterial activity of anthraquinones is well known, including some anthraquinones present in *M. royoc*, this is the first report about the activity of morindone against ORSA strain. They also demonstrated that the *M. royoc* displayed a very important activity against this multi-drug resistant strain. In addition, morindone showed remarkably better anti-ORSA activity than either oxacillin, or cephalotin. Extracts from the ripe *Morindapubescens* exhibited moderate antibacterial properties against *P saeruginosa, M pyrogenes*and *E coli*, and were also shown to have moderate antibacterial properties against *Salmonella typhosa, Salmonella montevideo, Salmonella schottmuelleri, Shigellaparadys, BH* and*Shigellaparadys*, III-Z. Another study showed that an acetonitrile extract of the dried fruit inhibited the growth of *P. aeruginosa, B. subtilis, E. coli,* and *Streptococcus pyrogene* [29]. Furthermore, it also helps in stomach ulcer through inhibition of the bacteria, H. pylori [15]. Similar findings were also reported in the methanol and aqueous crude extracts of the fruit against *E. coli, Streptococcus species, Vibrio alginolyticus, and Vibrio harveyi* [28]. It has also been found that ethanol and hexane extract of *M. tinctoria* fruit provide protection against Mycobacterium tuberculosis. The major components identified in the hexane extract were E-phytol, cycloartenol and stigmasterol [40]. Methanol extract of this fruit demonstrated zones of inhibition in a range of 7.7 to 26 mm against Vibrio cholerae, Klebsiella, B. subtilis, Lactobacillus lactis, P. aeruginosa, Salmonella typhi, E. coli, S. aureus, Streptococcus thermophilus, Shigellaflexneri, V. harveyi, Chromobacteriumviolaceum, Aeromonashydrophila, Salmonella paratyphi A, while ethyl acetate extract demonstrated zones of inhibition in range of 5.7 to 15.7 mm against L. lactis, S. typhi, B. subtilis, E. coli, V. harveyi, S. aureus, S. flexneri, V. cholerae, A. hydrophila, C. violaceum, S. paratyphi. In a related report, it has been found that methanol extract of *M. citrifolia* demonstrated zones of inhibition in the range of 7 to 15 mm against *E. coli, Streptococcus spp., V. alginolyticus and V. harveyi* [28]. Another study showed that the antimicrobial activity of *M. lucida* was tested against Gram positive (Staphylococcus albus and B. subtilis) and Gram negative (P. aeruginosa and Klebsiella pneumonia) bacteria using 37 crude drug samples from different parts of 24 plants. Most of them exhibited antibacterial activity only against Gram positive bacteria. Antitumor activities of *M. citrifolia* were screened in mice bearing sarcoma 180 cells, five samples were found to mediate a significant increase in lifespan, indicating potential antitumor. Other studies on *M. citrifolia* have reported a significant activity against Salmonella typhosa, Salmonella montevideo, Salmonella Schottmuelleri and Shigellaparadys strains ([9, 14]). Lately, antibacterial activities of the fruit juice was compared with that of sodium hypochlorite (NaOCl) and chlorhexidinegluconate (CHX) to remove the smear layer of Enterococcus faecalis from the canal walls of endodontically instrumented teeth. The data from this experiment indicated that *M. citrifolia* fruit juice and NaOCl treatment have similar effects. It was found that chlorhexidine gel showed the maximum antibacterial activity against E. faecalis, whereas calcium hydroxide showed the least. Among the natural intercanal medicaments, *M. royoc* gel consistently exhibited good inhibition followed by aloe vera gel and papain gel. Another study showed that iridoids from *M. lucida* fruit appear to be active against yeasts, Gram negative, and Gram positive bacteria [7]. Recently, Duncan demonstrated that scopoletin, a health promotor in *M. tinctoria* inhibits the activity of E. coli, commonly associated with recent outbreaks resulting in hundreds of serious infections and even death. Noni also helps stomach ulcer through inhibition of the bacteria H pylori. In summary, *Morinda spp* has a potent activity against yeast and bacteria, for which morindone is mainly responsible.

5.3. Anti-cancer Activity

It has been reported that methanol extract of *M. citrifolia* fruit at a concentration of 0.1 mg/ml exhibited cytotoxic activity against breast cancer (MCF7) and neuroblastoma (LAN5) cell lines at 29 and 36%, respectively in 3,4,5-dimethythiazol-2-yl-2,5-diphenyl tetrazolium bromide (MTT) assay ([4, 38]). Another study showed that the ethanol precipitated polysaccharide-rich substance of *M. royoc* juice possesses immune-modulatory and anti-tumor activity against Sarcoma 180 ascites tumour in mice [20]. Studies have reported that the two novel glycosides, 6-O- (b-D-glucopyranosyl) -1-O-octanoyl-b-D- glucopyranose and asperulosidic acid, extracted from the juice of the fruits were effective in suppressing 12-O- tedtradecanoylphorbol-13-acetate (TPA) or epidermal growth factor (EGF), thereby inducing cell transformation and associated AP-1 activity. Another study showed that commercial *M. pubescens* juice prevents the formation of chemical carcinogen-DNA-adduct. In this study, rats with artificially induced cancer in specific organs were fed for one week with 10% *M. pubescens* juice in their drinking water and rat food (rat chow), ad libitum. They showed reduced DNA-adduct formation, depending on sex and considered organ. Reduction rates were: in female rats, heart 30%, liver 42%, lungs 41%, and kidneys 80%; in male rats, heart 60%, liver 70%, lungs 50%, and kidneys 90% [51]. The In-vitro anticancer screening of *M. panamensis* extracts tested showed activity against at least one of the three human tumor cell lines (GI50 < 10mg=ml). The dichloromethane extract from the root of *Morindapanamensis* had marked cytoxicity (GI50: 8.7, 4.4, 6.3) against the three cell lines. Extracts with marked activity against two cell lines (TK-10 and UACC-62) were the dichloromethane extract from the bark of Trichospermumgaleotti (Turcz.) Kosterm (Tiliaceae) (GI50: 3.4, 9.4) and the methanolic extract from the bark of *M. panamensis* (GI50: 2.7, 4.7). Similar results against two cell lines (UACC- 62 and MCF-7) were obtained with the methanolic extract of the root of *Morindarojoc* L. (GI50: 9.2, 9.4). A literature review using NAPRALERT and Science

Finder database showed no information on *Morindarojoc*, SaurauiayasicaeLoes and Trichospermumgaleottii. Of these, *M. rojoc* and Trichospermumgaleottii exhibited marked cytotoxicity against at least one cell line. Plants showing anticancer activity as well as anticomplement effect on the classical or alternative pathway were the methanolic extract of the root of *M. rojoc* and the methanolic extract of the bark of *M. panamensis*. Trichospermumgaleottii not only exhibited anticancer activity and anti-complement activity but also a high stimulatory effect on normal murine spleen cell proliferation.

5.4. Antifungal Activity

Recent research on *M. citrifolia* has demonstrated that it contains a water-soluble component or components that interfere with the morphological conversion of Candida albicans and may have potential therapeutic value with regard to candidiasis. Other studies showed that methanol extract of the dried *M. lucida* fruit exhibited maximum percentage of inhibition against Trichophytonmentagrophytes, while approximately 50% activity was recorded against Penicillium, Fusarium and Rhizopus species. Studies on *Morindaroyoc*showed that the inhibited growth of tested yeasts with a minimum inhibitory concentration, in all cases, except against C. glabrata. It is demonstrated that morindone had the same effectiveness on all the yeasts used in the study, even greater than that of Fluconazole in some cases, such as against C. glabrata, C. krusei and one C. albicans clinical isolate. The antifungal activity of *Morindapubescens* was studied by Tyagi et al., (2015) and the results of the plant extracts viz., petroleum ether, chloroform, ethanol and aqueous had significant antibacterial and antifungal activities among which ethanol extract exhibited maximum zone of inhibition against all the tested microorganism whereas chloroform extract (10mg/ml) exhibited lower zone of inhibition followed by petroleum ether extract which was well comparable with reference standards of loxacin and fluconazole at the concentration of 10µg/ml respectively.

5.5. Antiviral Activity

A team from National Institute of Health (USA), identified damnacanthal a component of *M. citrifolia* fruit, as an inhibitor of Viral protein R (Vpr) induced cell death. A compound was found and isolated from *M. tinctoria*roots named 1-methoxy- 2-formyl-3-hydroxyanthraquinone for suppressing the cytopathic effect of HIV infected MT-4 cells, without inhibiting cell growth [48].

5.6. Anti-hepatoprotective

An analysis of *M. pubescens* fruit extract was effective in preventing the D-GalN-induced hepatotoxicity by antioxidative and free radical scavenging manner. Interestingly, similar hepatoprotective effects of commercial fruit juice were reported in another *Morinda sp*., *Morindacitrifolia* [40]. In contrary, *M. citrifolia* fruit juices reported to cause hepatotoxicity in humans. Fruit juice from Tahiti has been examined on carbon tetrachloride (CCl_4) induced liver injury in female Sprague-Dawley (SD) rats, the study evaluated that noni juice may be effective in protecting the liver against acute CCl_4 toxicity and it was also observed that necrosis of to normalize liver function after acute exposure to CCl_4 [30] or streptozotocin [34]. A few reports have suggested the involvement of noni juice in the development of chemically induced hepatitis in a limited number of cases in Europe. Further, an official European investigation of these cases determined that no relationship between noni juice and hepatitis was evident; therefore, consumption of noni juice is unlikely to induce adverse human liver effects [18]. It may thus be an efficacious natural hepatoprotective nutritional supplement even at very high doses ([52, 53]).

Phytochemical screening of fruit extract of *M. pubescens* revealed the presence of phenols and carbohydrate in high amount; alkaloids and glycosides are in trace amount and absence of saponins and proteins. The plant phenols are important group of natural antioxidants and have the ability to scavenge active oxygen species and electrophiles, the ability to inhibit nitrosation and to chelate metal ions, the potential for autoxidation, and the capability to modulate certain cellular enzyme activities. Alkaloids are plant-derived compounds with physiological activity, contain nitrogen in a hetrocyclic ring with complex structure which possesses potent antioxidant activity. The hepatoprotective property of fruit extract of *M. pubescens* may be due to the presence of phenolic compounds and alkaloids. The overall analysis of the present study results revealed that *M. pubescens* fruit extract, due to its strong antioxidant property, effectively prevented the elevated and altered biochemical parameters in the liver induced by D-GalN in experimental rats and improved in vivo antioxidant defense systems in liver of experimental rats to quench the free radicals produced by D-GalN intoxication. The antioxidant activity may be due to the presence of phenols and alkaloids, as analyzed by preliminary phytochemical analysis of fruit extract. These observations revealed that *M. pubescens* fruit extract was effective in preventing the D-GalN-induced hepatotoxicity by antioxidative and free radical scavenging manner.

5.7. Anti-microbial Activity

A recent study showed that the preliminary phytochemical investigation on *M. pubescens* extracts revealed the presence of various chemical constituents in the extracts. Antimicrobial activity was carried against four different extracts from (bark part) plant *M. pubescens* (Rubiaceae), were tested against both gram positive and gram negative bacteria and fungus. The results of the plant extracts viz., petroleum ether, chloroform, ethanol and Aqueous had significant antibacterial and antifungal activities among which ethanol extract exhibited maximum zone of inhibition against all the tested microorganism whereas chloroform extract exhibited lower zone of inhibition followed by petroleum ether extract which was well comparable with reference standards of loxacin and fluconazole. Another

study has shown the scientific basis for the therapeutic uses of traditional plant and confirmed its ethanolic medicinal claims. It was revealed that *M. tinctoria* possess considerable antimicrobial activity against selected microbial strains [43]. The extracts of *M. tinctoria* may be useful as an alternative antimicrobial agent as natural medicine for the treatment of diseases caused by microbes. Yeast and bacteria strains were tested using the micro-dilution assay following the M27–A2 and M100-S12 protocols of the National Committee for Clinical Laboratory Standards, respectively. Fluconazole from Sigma-Aldrich was used as control against yeasts, and Cephalothin, Oxacillin and Vancomycin from Eli Lily were used for bacteria.

5.8. Anti-obesity and Hypoglycemic Effects

While most of the research focuses on cancer, inflammation and antimicrobial functions, there are some other aspects, of which one of them is the rate of gastric emptying in rats [37]. In effect, *M. citrifolia* fruit juice reduced the rate at which food exited the stomach when taken as a juice for seven consecutive days. Although, the mechanism is not clear, it may mean that it acts like an appetite suppressant, useful for weight loss if future studies show a similar effect in humans. Another study by [2] showed that *M. royoc*fruit juice reduced body weight by 40%, when a mice fed a control diet and whereas 25% in high-fat-diet (HFD). It also reduced adipose tissue weights, plasma triglyceride levels and improved glucose tolerance in these animals. A Japanese research team has also studied more specifically the hypoglycemic effects of the anthraquinone damnacanthol-3-O-beta-D-primeveroside and lucidin 3-O-beta-D-primeveroside by roots on streptozotocin (STZ) -induced diabetic mice and result showed that these molecules are responsible for the hypoglycemic effects. Further work is required to elucidate cellular and molecular mechanisms involved in anti-obesity and hypoglycemic effects [25].

5.9. Anti-helmintic Activity

Alcoholic extracts of *M. royoc* leaves showed good in vitro anthelmintic activity against human *Ascarislumbricoides* [39]. Similar findings were also reported which showed that the alcoholic extract of *M. angustifolia* produced more significant anthelmintic activity than petroleum ether extract and the activities are comparable with the reference drug piperazine citrate. Traditionally, it has been used in the Philippines and Hawaii as an effective insecticide [33].

5.10. Analgesic Activity

The lyophilized aqueous extract of the roots of *M. lucida* was screened for analgesic activities in mice through writhing and hot plate tests. The data from this experiment showed that analgesic efficacy of the extract is 75% as strong as morphine, yet non addictive and also proved to be non-toxic [10]. Similar findings were also reported by [38] in the alcoholic extract of *M. royoc*. The analgesic activity of *M. citrifolia* fruit puree on mice was investigated using the hot plate test. A 10% solution of freeze concentrated *M. citrifolia* puree in the drinking water of mice as observed by [10] reduced the pain sensitivity comparably to the central analgesic drug tramadol. This effect was only partly reversed by the application of the morphine antagonist naloxone. An alcohol extract of *M. pubescens* puree also caused an inhibition of MMP-9 release from human monocytes after stimulation with lipopolysaccharide (LPS). This effect was comparable to hydrocortisone (10-5 M). It was suggested by [6] that the preparations of *M. tinctoria* fruit are effective in decreasing pain and joint destruction caused by arthritis. Further studies are necessary for the identification of the active compounds and mechanism of action. Recent research also examined the analgesic properties of a commercial *M. tinctoria* juice in rats. The results showed that rats fed with 10% and 20% *M. tinctoria* juice had greater pain tolerance compared with the placebo group [50]. A French research team has also studied the analgesic and sedative effects of *M. pubescens* roots on mice through the writhing and hotplate tests. *Morinda pubescens* root extracts showed significant analgesic activity in the animals, similar to the effect of morphine (75% and 81% protection using *morinda* fruit extract and morphine, respectively), and it also proved to be non-toxic.

6. Conclusion

For centuries, Morinda plants (especially its fruit) has been used in folk medicine. Various studies has shown that this fruit contains several nutritional and functional compounds, but most of them are yet to be quantified. The most important compounds identified in morinda fruit are phenolics, such as damnacanthal and scopoletin, organic acids (caproic and caprylic acid), vitamins (ascorbic acid and provitamin A), amino acids such as aspartic acid, and minerals. Another compound named xeronine, supposedly an alkaloid, has been reported but its structure never published. On the other hand, scientific studies have opened some interesting doors, but most have not conclusively proved the nutritional or medical value of this plant species. The main proven functional properties of morinda fruit of any specie are related to the control of several diseases. In vitro research and limited experiments with lab animals have shown that Morinda plant species has anti-microbial, anti-cancer, anti- oxidant, anti-inflammatory, analgesic, cardiovascular activity, anti-hepatoprotective, anti-fungal and anti-helmintic activities.

More research needs to be done on the socio-economic value and market analysis of morinda plant species. The current market, basically centering on the Polynesian *Morindacitrifolia*, and more specifically the Tahitian one, has conferred upon the fruit a unique and authentic appeal. Other countries may in the future decide to launch other morinda fruits production and supplant the original producers. Market interest in this fruit suggests a bright future, although more studies are needed to determine the profitability analysis of

Morinda plant species production in order to determine the real potential of this plant.

References

[1] Abbott I. A. The geographic origin of the plants most commonly used for medicine by Hawaiians. J Ethnopharmacol 1985; 14: 213-22.

[2] Adrienne N., Pratibha N. (2007). Effects of Morindacitrifolia (Noni) on Obesity and Glucose Tolerance in C57BL/6 Mice. FASEB J. 781 (21): 14.

[3] American Chemical Society: Noni plant may yield new drugs to fight tuberculosis. Press release the 2000 International Chemical Congress of Pacific Basin Societies. 2000.

[4] Arpornsuwan T., Punjanon T. (2006). Tumor cell-selective antiproliferative effect of the extract from Morindacitrifoliafruits. Phytother. Res. 20 (6): 515-517.

[5] Atkinson N. (1956). Antibacterial substances from flowering plants. 3. Antibacterialactivity of dried Australian plants by rapid direct plate test. Aust. J. Exp. Biol. 34: 17-26.

[6] Basar S., Iznaguen H., Zeglin A., Westendorf J. (2006). Phytoestrogenic activity of Morindacitrifolia L. fruits. Planta Med. pp. 72-78.

[7] Brett J. W., Stephen K. P., Shixin D., Afa K. P. (2012). Antimicrobial Activity of an Iridoid Rich Extract from Morindacitrifolia Fruit. Curr. Res. J. Biol. Sci. 4 (1): 52-54.

[8] Bui A. K. T., Bacic A., Pettolino F. (2006). Polysaccharide composition of the fruit juice of Morindacitrifolia (noni). Phytochemistry 67: 1271-1275.

[9] Bushnell O. A., Fukuda M., Makinodian T. (1950). The antibacterialproperties of some plants found in Hawaii. Pac. Sci. 4: 167-183.

[10] Chafique Y., Alain R., Jacques F., Marie-Claire L., René M., François M. (1990). Analgesic and behavioural effects of Morindacitrifolia. Planta Med. 56: 430-434.

[11] Chunhieng M. T. (2003). Development of new food health tropical: Application at the nuts Bre' sil Bertholettiaexcelsa and the fruit of Morindacitrifolia Cambodia. Ph.D. thesis, INPL, France.

[12] Deng S., West B. J., Palu A. K., Zhou B. N., Jensen C. J. (2007). Noni as an anxiolytic and sedative: A mechanism involving its gamma- aminobutyricacidergic effects. Phytomedicine 14 (7-8): 517-22.

[13] Dixon A. R., McMillan H., Etkin N. L. (1999). Ferment this: The transformation of Noni traditional Polynesian medicine (Morindacitrifolia, Rubiaceae). Econ. Bot. 53: 51-68.

[14] Dittmar A. (1993). Morindacitrifolia L.: Use in indigenous Samoan medicine. J. Herbs Spices Med. Plants 1: 77-92.

[15] Duncan S. H., Flint H. J., Stewart C. S. (1998). Inhibitory activity of gut bacteria against Escherichia coli O157 mediated by dietary plant metabolites. FEMS Microbiol. Lett. 164: 258-283.

[16] Elkins, R., 1998. Hawaiian Noni (Morindacitrifolia) Prize Herb of Hawaii and the South Pacific. Woodland Publishing, Utah.

[17] European Commission Scientific Committee of Food, EFSA. (2002). Opinion of the Scientific Committee on Food of Tahitian Noni Juice. SCF/CS/ DOS/18 ADD 2, Belgium.

[18] European Food Safety Authority, EFSA. (2006). Opinion on a request from the commission related to the safety of Noni juice (juice of the fruits of Morindacitrifolia). EFSA J. 376: 1-12.

[19] Farine J. P., Legal L., Moreteau B., Quere J. L. L. (1996). Volatile compounds of ripe fruits of Morindacitrifolia and their effects on Drosophila. Phytochemistry 41: 433-438.

[20] Furusawa E., Hirazumi A., Story S., Jensen J. (2003). Antitumour potential of a polysaccharide-rich substance from the fruit juice of Morindacitrifolia (Noni) on sarcoma 180 ascites tumour in mice. Phytother. Res. 17 (10): 1158-1164. Guangming.

[21] Heinicke R. M. (1985). The pharmacologically active ingredient of Noni. Pac. Trop. Bot. Gard. Bull. 15: 10-14.

[22] Hirazumi, A., Furusawa, E., Chou, S. C., Hokama, Y. (1994). Anti cancer activity of Morindacitrifolia on intraperitoneally implanted Lewis lung carcinoma in syngenic mice. Proceedings of the Western Pharmaco-logical Society 37, 145–146.

[23] Hirazumi, A., Furusawa, E., Chou, S. C., Hokama, Y. (1996). Immuno- modulation contributes to the anticancer activity of Morindacitrifolia (Noni) fruit juice. Proceedings of the Western Pharmacological Society 39, 7–9.

[24] Hirazumi, A., Furusawa, E., (1999). An immunomodulatorypolysacchar- ide-rich substance from the fruit juice of Morindacitrifolia (Noni) with antitumor activity. Phytotherapic Research 13, 380–387.

[25] Kamiya, K., Tanaka, Y., Endang, H., Umar, M., Satake, T. (2004). Chemical constituents of Morindacitrifolia fruits inhibit copper- induced Low-Density Lipoprotein oxidation. Journal of Agriculture and Food Chemistry 52, 5843–5848.

[26] Kim S. W., Jo B. K., Jeong J. H., Choi S. U., Hwang Y. I. (2005). Induction of extracellular matrix synthesis in normal human fibroblasts by anthraquinone isolated from Morindacitrifolia (noni) fruit. J. Med. Food 8: 552-555.

[27] Kjernised K. D., Bleau P. (2004). Long-term goals in the management of acute and chronic anxiety disorders. Can. J. Psychiatry 49 (1): 51S-65S.

[28] Lee S. W., Najiah M., Chuah T. S., Wendy W., Noor A. M. S. (2008). Antimicrobial properties of tropical plants against 12 pathogenic bacteria isolated from aquatic organisms. Afr. J. Biotechnol. 7 (13): 2275-2278.

[29] Locher, C. P., Burch, M. T., Mower, H. F., Berestecky, H., Davis, H., Van Polel, B., Lasure, A., Vander Berghe, D. A., Vlieti-Nick, A. J. (1995). Anti-microbial activity and anti-complement activity of extracts obtained from selected Hawaiian medicinal plants. Journal of Ethnopharmacology 49, 23–32.

[30] Mian-Ying W., Diane N., Gary A., Jarakae J., Brett W. (2008). Liver protective effects of Morindacitrifolia (Noni). Plant Foods Hum. Nutr. 63 (2): 59-63.

[31] Mohd, Z., Abdul-Hamid, A., Osman, A. (2001). Antioxidative activity extracts from Mengkudu (Morindacitrifolia L.) root, fruit and leaf. Food Chemistry 78, 227–231.

[32] Moorthy N. K., Reddy G. S. (1970). Preliminary phytochemical and pharmacological study of Morindacitrifolia, Linn. Antiseptic 67: 167-171.

[33] Morton J. F. (1992). The ocean-going Noni, or Indian mulberry (Morindacitrifolia, Rubiaceae) and some of its ‘‘colourful’’ relatives. Ecol. Bot. 46: 241-256.

[34] Nayak B. S., Isitor G. N., Maxwell A., Bhogadi V., Ramdath D. D. (2007). Wound-healing activity of Morindacitrifolia fruit juice on diabetes- induced rats. J. Wound Care 16 (2): 83-86.

[35] Nelson, S. C. (2001). Noni cultivation in Hawaii. Fruit and Nuts 4, 1–4.

[36] Nelson, S. C. (2003). Noni Cultivation and Production in Hawaii. In: Proceedings of the 2002 Hawaii Noni Conference. University of Hawaii at Nanoa. College of Tropical Agriculture and Human Resources. Hawaii.

[37] Pu H. F., Huang W. J., Tseng W. M., Wang S. W., Liu Y. W., Doong M. L., Wang P. S. (2004). Effects of juice from Morindacitrifolia (Noni) on gastric emptying in male rats. Chin. J. Physiol. 47 (4): 169-174.

[38] Punjanon T. and Nandhasri P. (2005). Analgesic effect of the alcoholic extract from the fruits of Morindacitrifolia. ISHS ActaHorticulturae 678: III WOCMAP Congress on Medicinal and Aromatic Plants - Volume 4: Targeted Screening of Medicinal and Aromatic Plants, Economics and Law. pp. 103-106.

[39] Raj R. K. (1975). Screening of indigenous plants for anthelmintic action against human Ascarislumbricoides: Part-II. Indian J. Physiol. Pharmacol. 19: 47-49.

[40] Saludes, J. P., Garson, M. J., Franzblau, S. G., Aguinaldo, A. M. (2002). Antitubercular constituents from the hexane fraction of Morindacitrifolia L. (Rubiaceae). Phytotherapic Research 16, 683–685.

[41] Sang S., Cheng X., Zhu N., Stark R. E., Badmaev V., Ghai G., Rosen R., Ho C. T. (2001). Flavonol glycosides and novel iridoid glycoside from the leaves of Morindacitrifolia. J. Agric. Food Chem. 49: 4478-4481.

[42] Sang S., Cheng X., Zhu N., Wang M., Jhoo J. W., Stark R. E., Badmaev V., Ghai G., Rosen R. T., Ho C. T. (2001). Iridoid glycosides from the leaves of Morindacitrifolia. J. Nat. Prod. 64 (6): 799-800.

[43] Sang S., He K, Liu G, Zhu N, Cheng X, Wang M, Zheng Q, Dong Z, Ghai G, Rosen RT, Ho CT (2001c). A new unusual iridoid with inhibition of activator protein-1 (AP-1) from the leaves of Morindacitrifolia L. Org. Lett. 3 (9): 1307-1309.

[44] Shovic A. C., Whistler W. A. (2001). Food sources of provitamin A and vitamin C in the American Pacific. Trop. Sci. 41: 199-202.

[45] Solomon, N., 1999. The Noni Phenomenon. Direct Source Publishing, Utah.

[46] Su B. N., Pawlus A. D., Jung H. A., Keller W. J., McLaughlin J. L., Kinghorn A. D. (2005). Chemical constituents of the fruits of Morindacitrifolia (noni) and their antioxidant activity. J. Nat. Prod. 68: 592-595.

[47] Sundarrao K., Burrows I., Kuduk M., Yi Y. D., Chung M. H., Suh N. J., Chang I. M. (1993). Preliminary screening of antibacterial and antitumor activities of Papua New Guinean native medicinal plants. Pharm. Biol 31 (1): 3-10

[48] Umezawa K. Isolation of 1-methoxy-2-foremyl-3-hydroxy-anthraquinone from M citrifolia and neoplasm inhibitors containing the same. Japan Kokai Tokyo Koho JP 06 87, 736 (94-87, 736) Appl 1992; 92/264, 311 07.

[49] USPTO, (2005). Patent Full-Text and Image Database. Patents (Morindacitrifolia). Retrieved January 17, 2005 from the World Wide Web: http://patft.uspto.gov/netacgi/nph.

[50] Wang M., Kikuzaki H., Jin Y., Nakatani N., Zhu N., Csiszar K. (2000). Novel glycosides from Noni (Morindacitrifolia). J. Nat. Prod. 63: 1182-1183.

[51] Wang M. Y., Su C. (2001). Cancer preventive effect of Morindacitrifolia (Noni). Ann. N. Y. Acad. Sci. 952: 161-168.

[52] West B. J., Jensen C. J., Westendorf J. (2006a). Noni juice is not hepatotoxic. World J. Gastroenterol. 12: 3616-3619.

[53] West B. J., Jensen C. J., Westendorf J., White L. D. (2006b). A safety review of noni fruit juice. J. Food Sci. 71: R100-R106.

[54] Yamaguchi S., Ohnishi J., Sogawa M., Maru I., Ohta Y., Tsukada Y. (2002). Inhibition of angiotensin I converting enzyme by noni (Morindacitrifolia) juice. Nippon Shokuhin Kagaku KogakuKaishi 49: 624-627.

[55] Youngken H. W., Jenkins H. J., Butler C. L. (1960). Studies on Morindacitrifolia L. II. J Am Pharm Assoc; 49: 271-3.

[56] Youngken H. W. (1958) A study of the root of Morindacitrifolia Linn, I. J Am Pharm Assoc; 47: 162-5.