# A Review Article of *Canarium ovatum* as a Potential Alternative Fatty Acid Source for Tilapia Feeds

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***Abstract***— *Tilapia cannot biosynthesize all essential fatty acids, requires supplementation to provide growth, and reproductive development. Fatty acids catalyzed the absorption of fat-soluble nutrients such as sterols and vitamins A, D, E and K. These nutritional requirements can be acquired from Pili Canarium ovatum. Pili are cultivated in Bicolandia, hardwood tree, bear fruits, the primary importance are the nuts for pastry products and expensive oil, used used in pharmaceutical products, industrial and culinary. Once pili are harvested the pulp just turned into waste or served as feed for husbandry and edible blanched vegetables. More importantly, pili pulp has an exceptional nutritional composition comparable to olive oil. The macro minerals are calcium, magnesium, potassium, and phosphorus. The iron, copper, zinc, chromium, and selenium are known essential minerals; cofactors for metabolic and physiological functions in the body. The fatty acids profile includes oleic acid (60.93%), palmitic acid (23.96%), palmitoleic acid (4.66%), stearic acid (2.64%), and linoleic acid (6.63%). Significant factors to produce for tilapia through feed inclusion, described with high digestibility, palatable and high metabolizable energy (ME). The optimum dietary requirement levels of n-6 acids estimated at about 1% for red belly tilapia, Tilapia zillii, and 0.5% for Oreochromis niloticus. The optimum n-3 fatty acids for tilapia is undetermined, the efficacy of both n-3 and n-6 PUFAs satisfy the physiological demand and bioconvert C18 PUFAs to long-chain HUFAs. However, undeniable that plant-based ingredient contained phytic and tannic, reduce mineral absorption in the body.*

***Keywords***— *Canarium ovatum, essential fatty acids, Tilapia.*

## I. Introduction

In Bicolandia, pili are symbolic pride and produced 80% of the country's production. The species of pili is dominant in Bicol and identified as *Canarium ovatum*, *Engl. (Burseraceae)* an indigenous fruit tree in the Philippines, with numerous species and four genera, (*Pham, 2015*). It is a deciduous tree measuring about 20-25 meters in height and 40-50 centimeters in diameter. This are abundantly found in the different provinces of Bicol (Southern Luzon), particularly in the provinces of Sorsogon, Albay and Camarines Sur. This thrives in the primary and secondary forests of low to medium elevations, (*Orwa et al., 2009*). These are mainly cultured for nuts or kernels and historically the Philippines hold the monopoly over-processed pili products globally. The pili is known for nut confections, culinary, cosmetic products, attested with curative properties against skin diseases and pili pulp oil used in worm treatment for livestock such as hogs and poultry, (*Tacio, 2010*).

Meanwhile the common practice in pili industry, pili pulp is totally discarded as waste, (*Pham 2020*) after processing the kernel into different types of sweets. Although this time oil extraction is getting more popular created an expensive oil which has exceptional nutritional properties and contain considerable quantities of bioactive compounds, (*Pham 2020)*, more beta-carotene, carotenoids, sterols, hydrocarbons, and xanthophyll, which makes it more nutritious than olive oil, (*Asuncion, 2006; Pham, 2014*). But the residue of this pili pulp oil extraction the pomace remains waste turned unnoticed with the other considerable nutrients of bioactive compounds present in the pulp meal, photochemicals, fatty acids and other valuable nutrients proven to be beneficial for food for animals, (*Pham 2020)*. This pili pulp pomace is a mixture of peel and fibrous pulp, a by-product that is usually fed to the livestock or used for compost. Nevertheless in some locality pili pulp is consumed as vegetable, blanched in boiling water, and the skin (*pericarp*) of the pili is removed; only the pulp is being eaten with fermented anchovy or siganids "*padas*" or sometimes eaten with sugar, fish sauce, salt, pepper or other condiments.

The macro minerals of pili pulp are K and Ca, (*Millena 2018*). Potassium is prominent mineral in pulp (2820+57 to 4300+41 mg/100g) and calcium containing 514+4 to 1090+9 mg/100g, *(Millena 2018).* Also there are ample amount of antioxidant properties, as indicated by δ-tocopherol higher in pili pulp oil (72.47 mg/100 g oil), also with a high concentration of the β-Carotene (very important carotenoid) at 56.89 mg/100 g oil. Another is Lycopene (13.60 mg/100 g oil) available in pili pulp but not in pili nut, (*Pham et al, 2015).* The variability concentration of nutrients is due to the plant's capacity to accumulate minerals, agricultural practices, and environmental factors, (*Moreda-Piñeiro et al.2016*), condition of the geographical region (*Chew et al.; 2011, Foster et al. 2002; Connor et al. 2002*) and cultivars technique (*Villareal-Lozoya et al. 2007; Tura et al. 2007*).

Since pili pulp has exceptional nutrients, it shows great potency as feed ingredient for tilapia. It contains high dietary fiber, phytonutrient and bioavailable phenolic antioxidant, (*Arenas & Trinidad, 2017*), ideal in the food chain and essential for human health, (*Steffens and Wirth, 1997*). Importantly pili pulp mixture does not pose any potential public health risk when used as a component for food and drug products, (*Arenas et al 2016).* It is also a source of hydrophilic and lipophilic bioactive compounds with high antioxidant functionality, (*Pham, 2020*). Now using pili pulp pomace as feed for tilapia are essentially higher in carbohydrates 45.8%, ether extract at 33.6%, protein at 8%, crude fiber at 3.4%, and energy value of 533 Cal per 100g, (*Maranon et al, 1954; Shiau, 1997; Stickney, 2006*). These properties create a huge potential as a feed ingredient for tilapia to have normal physiological functions, a natural immune system, promote growth, and reproduction, (*Alemayehu, 2018*), which the traditional feeds could not guarantee. Moreover, potential inclusion of plant ingredients increases the dietary carbohydrate content, these digestible carbohydrates (i.e. starch) constitute a partial alternative for the digestible energy (DE) supplied by fish oil or vegetable oils in diets, especially for species such as tilapia, (*Schramaet al, 2021).* The tilapia requires to sustain the metabolic process, growth, and reproduction, by supplementing the following nutrients: protein at 30- 40 %, (*Hafedh,1999; Siddiqui et al, 1988*), lipids at s 5.2%, (*Jauncey, 2000*), though carbohydrates do not have defined level.

Further species of tilapia required n-6 (*linoleic*) fatty acids, to a lesser extent with n-3 (*linolenic*) fatty acids, (*Jauncey, 2000*), and dietary lipids are at least 1% of n-6 fatty acids, (*Teshima et al., 1982*). The *Tilapia nilotica* is generally described with high Lipids levels of n-3 polyunsaturated fatty acids, e.g. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), (*Steffens, 2006*). There are also sufficient amounts of n-6 fatty acids linoleic acid and arachidonic acid, (*Steffens et al., 1993, 1997*). The marine species has 5 to 10 fatty acids while freshwater is 1 to 4 levels, acceptable to human nutritional requirements, (*Steffens, 2006*). Therefore both n-6 and n-3 fatty acids are vital to be incorporated in the diet of the tilapia because they cannot be synthesized by animals or humans, though it varies on the amount ingested through food, (*Steffens and Wirth, 1997*). Although lesser information yet for tilapia on the requirements of palmitic and oleic acid, however tested in Brazil these fatty acids were predominant saturated fatty acid identified in both freshwater and marine fish, (*Gutierrez et al, 1993*). Then oleic acid is most abundant monounsaturated fatty acid and it was found in higher levels in freshwater fish, (*Gutierrez et al, 1993; ANDRADE & LIMA et al, 1979).* It was proven that tilapia can bioconvert C18 (*palmitic acids*) PUFAs to long-chain HUFAs, conversion is dependent on the fatty acid composition of the diet. The conversion is higher in fish fed with vegetable oil diets rich in C18 PUFAs, compared with the fish fed fish oil diets rich in long-chain HUFAs, (*Lim et al, 2016*).

Therefore, utilizing pili pulp pomace as fatty acids source and other vital nutrients for tilapia feed is a practical strategy aside from smart initiative not to end up this in wastage. This will eventually limit the huge amount of carbon footprint globally, (*www.fishsite.com*). Besides, a primary advocacy of the aquaculture industry to revolutionize the limit of its dependency and total replacement of the fishmeal and fish oil without sacrificing its farm efficacy and sustainability. Especially i is estimated that the fishmeal shortage could reach from 0.4 to 1.32 million metric tons by 2050, (*Jones et al 2020*). That will significantly impair the aquaculture industry growth.

While it is undeniable that a plant-based ingredient has a higher content of phytic and tannic aside that reduces the mineral absorption, (*Reddy et al., 1982)* in the body of the animal. The precipitation of some proteins and formation of non-absorbable complexes may result in low availability of minerals (*Mole et al. 1993, Trinidad et al., 1996b*), retard the growth of the animal. To suffice these limitations, supplementation of enzymes and probiotics is suggested to be added to improve the nutritional absorption of nutrients to the body of the fish.

Since aquaculture products is a healthy food with high nutritive compounds thus regular eating of fish supplemented with various nutrients from pili pulp has great potential to prevent illnesses like heart disease, reduce cholesterol, cancer prevention, and other conditions that the society is confronting now. Therefore consumption of *tilapia nilotica* as food requires meeting the nutritional requirements for human health. Hence, incorporation of pili pulp in tilapia feed is an ideal improvement of the quality of tilapia, not just as a cheap source of protein among marginalized sectors but will improve its value in the market because of fortification of essential nutrients.

## II. Taxonomic Classification Pili

The pili were identified in 1883, cultivated in the Philippines since ancient times and considered as commercial crop, (*Coronel, 1996*). However, its cultivation is dominant in Bicol Region. The pili are adopted with distinct wet and dry seasons, and typhoon resistant trees. Being know as huge trees and hardwood, locally it is developed now as furniture's and other domestic uses. It is also considered as dioecious, deciduous, medium-sized to large tree, (*Coronel, 1996)*. There are almost seventy-five (75) known *Canarium* species, nine (9) of which are endemic in the Philippines and four of the genera under this family *Burceraceae*. The *Canarium* species has its existence in Malaysian Region, *Canarium indicum* is available in Solomon Island (known as 'ngali'), in Papua new Guinea pili is known as 'Galip', and in Vanuatu known as 'nangai',(*Coronel, 1996; Evans 1993).* Also in Thailand and Vietnam *Canarium album* is dominant in the area known as Chinese olive "samo cheen" the people consumed the pulp and kernel, (*Verheij and Coronel, 1991*). The species of *C. ovatum, C. indicum, C. album and C. luzonicum, (Coronel, 1996*), has high economic importance. But among the species *C. ovatum* has high economic potential (Coronel, 1996; *Pham 2015*).

Identification of pili species significantly lies in the concentration in proximate and fatty acid profiles that are attributed to their distinct variety, (*Millena & Sagum, 2018*). Also it is distinct in the pili that the anthesis or flowering of male and female pili, anther dehiscence, and stigma receptivity occurs in the late afternoon. The odor is emitted from the flowers that attract the pollination process by insects and it takes 12 months to ripen the pili fruit. The maturity of the pili fruit is determined by the change in exocarp color from green to dark purple to black.

## III. Economic Importance of Pili

There are wider opportunities of pili as a major crop export in global market, (*Pham 2015)* and Philippines dominates the world export market for pili (Canarium ovatum) products, (*Gallegos et al. 2013*). This is boosted by its exceptional nutritional composition comparable to olive oil. The economic analysis of oil extraction from pili pulp production will only cost PhP 599, compared to almost half the cost of importing olive oil from Spain estimated at PhP 1,310/kg. It shows an economic advantage in pili pulp oil production with a domestic resource cost (DRC) of 0.72 hence manifests considerable great economic potential especially it caters employment and profit. Last 2014, it was projected that the processing of pili pulp into



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oil, could utilize a total of 262,000 metric tons, which would make an amount of PhP 212 million, (*Catelo, et al, 2016*).

The increasing opportunities in pili industry is based on the demand not just as food (flavoring, beverages) but it is functional usage in pharmaceutical, cosmetics and other industrial purposes (natural essential oil as aroma, perfume and ornaments). These increasing consumer preferences especially on natural and personal care promoting healthy living was also boosted by strong economic growth in emerging markets in Asia, (*Beerling 2013, Ferrara 2013*).

The world's top importers used Pili oil for manufacturing soaps, detergents, perfumes, and other household goods, (*New Agriculturist, n.d*.). According to the *Observatory of Economic Complexity (2013),* several countries demand this product like in United States (US$ 739 million), France (US$ 321 million), China (US$ 303 million), the United Kingdom (US$ 270 million), and Germany (US$ 253 million). The estimated global need for essential oil was roughly US$ 5.51 billion in 2014 and is expected to reach US$ 11.67 billion by 2022, (*Grand View Research, Inc., 2015*).

## IV. Macro and Micro Minerals of Pili Pulp

A pili pulp has unique and substantial properties beneficial for fish and in human life. It contained higher Mg (pulp: 75.8–90.3%) and calcium (pulp: 15.8–40.9%), and tannic acid is higher in pulp, (*Millena, 2018*) which has protective effect on human skin. Aside from macro minerals such as calcium, magnesium, potassium, phosphorus and essential micro minerals like iron, copper, zinc, chromium, selenium, and many more that act as cofactors for many metabolic and physiological functions in the body, (*Moreda-Piñeiro et al. 2016; Kafaoglu, 2016*)

The pili pulp oil has high oleic fatty acid showed as omega -9 a major fatty acid, (*Pham 2015*). This is abundant in olive oil and other edible oils. The oleic acid most commonly preventing heart disease, cancer and reduce cholesterol in the body. In general, the pili pulp is unsaturated which makes it potential material for high-value specialty oil products, (*Chew et al. 2015; Pham & Dumandan, 2015; Azlan et al. 2010*), though pili kernel is less unsaturated than the pulp. After the pili pulp oil extraction the pili pomace (residue) still has ample source of quality dietary fiber and bioavailable phenolic antioxidants (*Arenas & Trinidad, 2017*). Then, comparing the unsaponifiable matter it is higher in pili pulp oil than in pili nut oil. Which the lipid molecular present in the unsaponifiable matter of the oils are carotenoids, tocopherols, and sterols, (*Pham 2015*).

Further the pili pulp nutritional composition has similarities with avocado with 28–36% oil, 46% carbohydrates, and 8% protein, 3% crude fiber (*Coronel 1996*; *Pham et al 2015*). Hence its oil color varies from yellow-green to dark green, due to procedural extraction, (*Pham et al, 2008*). Conversely, pili kernel oil contains higher oil approximately 70% comparable and even the oil characteristic has great similarity with olive oil but it contains more beta-carotene, carotenoids, sterols, hydrocarbons, and xanthophyll, which makes it more nutritious than olive oil, (*Asuncion, 2006; Pham, 2014*). Then the sweetness of pili oil is perfect for all types of food preparation and free from aflatoxin, (*Pham, 2012*). Aside from this advantage it is inexpensive option for olive oil since pili pulp is just a waste material from the pili nut processing industry.

The major fatty acids present in the oil of pili pulp were *oleic (60.93%), palmitic (23.96%), palmitoleic (4.66%), stearic (2.64%),* and *linoleic (6.63%).* Pili pulp oil has a higher oleic fatty acid value than pili nut oil, indicates by higher iodine number, (*Pham et al, 2015*). Interestingly the higher *oleic acid* in pili pulp oil is incomparable with most commercial oils and classified with highly monounsaturated oils such as olive oil because of the γ-linolenic fatty acid content of both pulp and kernel oils. Then, the antioxidation property is indicated by δ-tocopherol higher in pili pulp oil (72.47 mg/100 g oil), with a high concentration also of the β-Carotene, a very important carotenoid, (56.89 mg/100 g oil), (*Pham et al, 2015)*. Also, Lycopene (13.60 mg/100 g oil) is present in pili pulp but absent in pili nut, (*Pham et al, 2015)*

The free fatty acid number is an indicator of hydrolytic rancidity which is higher in pili pulp oil than for pili nut oil, which means more prone to oxidation and rancidity. These reactions are caused by the presence of *phenolics* and other acidic compounds present in the pili pulp. But it has resistance to hydrolysis, because of the long-chain unsaturated fatty acids, which requires refining the process to reduce the free fatty acid. This is a great advantage for the dietary purposes for fighting various fatal illnesses in human life and shows its significance to be eaten by tilapia since this fish is a common food for the consuming populace.

## V. Required Quality Feed Ingredient of Tilapia

The quality of feed is characterized by the ingredients having good digestibility, palatable and nutrient utilization and interference, or metabolizable energy (ME) for growth (respectively, $k_{gDE}$ and $k_{gME}$), (*Hixson, 2014; Schrama et al, 2012; Glencross et al, 2007)*. Another, factor of the bioavailability or digestibility of the nutrient in diet should be proportion in the feed digested and absorbed by the fish and transformed into growth, *(Hixson, 2014).* That will provide benefits for normal physiological functions, natural immune system, promote growth, and reproduction, (*Alemayehu, 2018*), which the traditional feeds could not guarantee. Therefore feed fortification should be applied to provide additional beneficial properties in the aquaculture feeds inclusion of probiotics, prebiotics, phytogenic substances, immune-stimulants, enzymes, hormones, mycotoxin binders, organic acids, *(Alemayehu, 2018)*. These are boosters to improve the growth performance of the fish that turns into profit.

There are required essential fatty acids that the fish needed to acquire only by meeting the supplying Long Chain (LC) Polyunsaturated Fatty Acids (PUFA) in the diet, specifically α-Linolenic Acid (LNA, 18:3ω3) and Linoleic Acid (LA, 18:2ω6), with varying requirements for eicosapentaenoic acid (EPA, 20:5ω3) and docosahexaenoic acid (DHA, 22:6ω3) depends on species, (*Hixson, 2014*). Then, tilapia required a higher amount of n-6 FA compared to n-3 FA for maximum growth with a dietary requirement of approximately 1% of n-6 FA in their diets, (*Aziza, 2013l; Bazaoglu, 2012*).

The innovation of the feeds now supplementing high energy lipid to convert into muscle protein, created the most efficient feeds for fish, (*Hixson, 2014*). This is the new highly digestible nutrient-density extruded feeds (46 to 50% protein, 20 to 24% fat) achieved a Feed Conversion Ratio (FCR) of about 0.9-1.2 for rainbow trout (*Oncorhynchus mykiss*) grown to market size, (*Ganguly et al, 2013*). The increased digestible nutrient and energy of the feeds and feed extrusion process, with higher lipid levels, improved starch gelatinization (increases digestible energy content and utilization), and improved pellet characteristics (durability, buoyancy, etc.), (*Tacon et al, 2011*).

There are numerous factors to consider in choosing feed ingredients; availability of raw materials and stability, quality of nutritional composition of the ingredient, cost, and functionality. Most importantly emphasize the increasing price of feeds mostly caused by extreme competition over the commonly used conventional ingredients. That sorting to alternative ingredients either plant or animal is being sourced out now to address the demand and the declining raw material resources. However typically plant based ingredients has anti-nutritional properties like the presence of tannins and phytic acid, observed to retard animal growth. These compound substances (tannins and phytic acid) are common in the pili pulp. These limitations require suppressing the phytic and tannic acid through the inclusion of phytase bacteria, probitics, mineral supplementation and refinement of the procedural activity, purposely to improve the body absorptions of the nutrients from pili pulp or any types of plant.

The nutritional quality of pili pulp was already tested in laying performance of quails, affirmed from the study of *Ultra et al, 2018,* at a 15% level of supplementation. It was observed with significant increase in the weight of eggs associated with the high presence of *tocophenol* in pili pulp. Although there is no better expression on the color of egg yolk of the quail because pili pulp contained high xanthophylls pigment, presumed that it was degraded during the process of drying, thus requires to develop the technique of drying to preserve the reduction of pigments so that it will improve the quality of egg yolk color.

## VI. Traceability of Phytic and Tannic Acid

The phytic acid in pili pulp is approximately four times lower compared to the kernel, (*Millena 2018*), most concentrated sources tend to be from the seeds, legumes in cotyledon, (*Nissar et al, 2017*; *Harland & Morris, 1995; Greiner & Konietzny, 2006*). In the pili variety, Mayon#1 has the lowest amount of phytic acid among Pili pulp varieties and *Orbase* and *Lanuza* have the highest amount. Another, the PA increases when it is in a repining stage in the seed, (*Nissar et al, 2017*). There are potential technique to reduce the phytic acid like exposure to high temperatures by cooking, sprouting, soaking, malting, hydrothermal processing, and fermentation, (*Kumar et al. 2010; Nissar et al, 2017*). Then in fact the suppression of phytic acid was done by adding *phytase* to the diet of tilapia which improved the growth performance, digestibility, and utilization of dietary protein and phosphorous, (*Riche et al., 2001; Heindl et al., 2004; Liebert and Portz, 2004; Phromkunthong et al., 2004).* Apparently, the detailed methods to minimize the anti-nutritional properties of any plant ingredients could be through soaking, cooking, sprouting, malting, hydrothermal processing, and fermentation, (*Kumar et al. 2010; Nissar et al, 2017*), however requires to consider the ideal temperature to protect the amino acids from degradation, and decrease the leaching of water-soluble components (*Riche et al., 2001; Heindl et al., 2004*).

The normal biological process of the phytic acid through fermentation in the colon of the animals by bacterial flora (microbial *phytase*) may result in hydrolysis products (dephosphorylation) reduce mineral binding capacity and become more available for absorption in the colon (*Harland & Morris, 1995; Sandström et al. 1990; Cowieson et al. 2016*). But in human beings despite the phytate that affects the mineral absorption, demonstrate beneficial effect such as hypoglycemic hypocholesterolemic, hypolipidemic, antioxidant, and has anti-cancer property (*Pallauf et al., 1998; Katayama et al. 1997; Thompson, 1993; Minihane & Rimbach, 2002; Raboy, 2003; Shamsuddin et al. 1996; Somasundar et al. 2005*).

Another anti-nutritional substance available in pili pulp is tannic acid, also a naturally occurring in plants polyphenol is composed of a central glucose molecule derivatized at its hydroxyl groups with one or more galloyl residues, possess antioxidant (*Lopes et al., 1999, Ferguson, 2001, Wu et al., 2004, Andrade et al., 2005*), antimutagenic (*Ferguson, 2001, Horikawa et al., 1994, Chen and Chung, 2000*) and anticarcinogenic properties (*Horikawa et al., 1994, Athar et al., 1989, Gali et al., 1992, Nepka et al., 1999).* The tannic acid has an antioxidant mechanism that decreases iron absorption and impaired the ecological balance of the gastrointestinal flora of mice, (*Samanta et al, 2009*). This substance hampers the absorption of the minerals in the body of the animal. On the other hand, the tannic acid level in pili pulp is higher, but lower in the kernel, (*Millena 2018).* The precipitation of some proteins and formation of non-absorbable complexes may result in low availability of minerals, (*Mole et al. 1993, Trinidad et al., 1996b*). The tannins are complex secondary metabolites present in the plant kingdom that bind with protein and make it unavailable; however, recently proven to have the potential to replace conventional ingredients, with great health benefits, particularly the control of zoonotic pathogens such as Salmonella., (*Hassan et al, 202*0). The polyphenolic nature of tannic acid, its relatively hydrophobic "core" and hydrophilic "shell" are the features responsible for its antioxidant action *(Isenburg et al., 2006).* These are present in the bark and fruits of many plant species, (*Lopes et al., 1999*). The safe dosage ranges from 10 to 400 μg, depending on the type of food to which it is added, (*Chen and Chung, 200*0). It has inhibitory and preventive effects in various human cancers and cardiovascular diseases may be related to the antioxidant activity of polyphenols, (*Andrade et al., 2005*) aside from inhibiting skin, lung, and forestomach tumors induced by polycyclic aromatic hydrocarbon carcinogens and *N*-methyl-*N*-nitrosourea observed in mice (*Vance and Teel, 1989, Khan et al., 1988*). This tannic acid is comparable with commercial and standard antioxidants such as BHA, BHT, α-tocopherol, and Trolox commonly used by the food and pharmaceutical industry. Therefore despite the anti-nutritional properties of pili pulp this describes importance of its inclusion in aquafeed (tilapia) purposely to save human lives.

## VII. Conclusion

Gaining quality nutrients from fish is attainable by providing the appropriate nutritional requirements by the fish like obtaining higher level of fish fatty acids and other related nutrients. Through fish consumption with nutritionally balanced composition this will eventually benefit the human health by preventing and catalyst to treat fatal illnesses. These substantial nutrients can be derived from Pili pulp pomace a promising alternative fatty acid source and as feed ingredient for tilapia because of its exceptional nutritional components. It is an opportunity for mass utilization of the discarded pili pulp pomace which is untapped for commercialization. However, it is necessary to correlate the nutritional and anti-nutritional traits for possible use in fish feeds formulation. Further, it requires developing the appropriate process to remove or minimize the anti-nutritional properties of the pili and reduce the degradation of the essential fatty acids. Finally tests its efficacy in the different life stages of tilapia and other fish species.

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