Overview of Phytochemical Compounds and Pharmacological Activities of Ananas Comosus L. Merr

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ABSTRACT
Ananas comosus L. Merr, known as pineapple, belongs to the Bromeliaceae family. This plant has been used as traditional medicine and continues until now in conventional herbal medicine. The pineapple was distributed in some countries such as China, India, Indonesia, Malaysia, Thailand and originated from South America. This article delved the scientific work about Ananas comosus focusing their usage as traditional medicine, chemical compounds and biological activities. All of the pieces of information were obtained from the scientific literature such as Science Direct, Google Scholar, Scopus and PubMed. Based on the literature survey, different parts of pineapple (Ananas comosus) are used in traditional medicine, used as an anti-inflammatory agent, anti-oedema, digestive disorder, antimicrobial, vermicide, and purgative. Phytochemical compounds from A. comosus have been provided, including ascorbic acid, quercetin, flavones-3-ol, flavones, and ferulic acid. The crude extracts of A. comosus have many pharmacological activities such as anti-fungal, anti-inflammatory, antioxidant, antibacterial. This discovery becomes possible due to scientific isolation and in vivo or in vitro analysis of A. comosus.

INTRODUCTION
Ananas comosus (pineapple) belongs to subfamily Bromeliodeae and family Bromeliaceae. Bromeliaceae contained around 2794 species and 56 genera. A. comosus has synonym name, Bromelia comosa, Bromelia ananas, Ananas sativus, Ananassa Sativa (Mondal et al., 2011). This plant originated in Latin America, definitely from Amazon river at the north region, A. comosus is now grown widely, in tropical and subtropical regions, this plant became the third commercial tropical fruit in the world and fourth most cultivated fruit crop. According to many researchers, A. comosus was released to various regions of the world through historians and travellers, mainly the Portuguese and Spanish who disseminated information regarding A. comosus. Mutations in A. comosus such as size, seedless, enhancement sweetness, juiciness and the improved flavour was developed since their founding. This plant has been utilised as a traditional medicine in many countries, and native civilisation (Mondal et al., 2011) and this medicinal of A. comosus are related to bromelain, it is a group proteolytic enzymes. It has been presented to have several biological activities such as antithrombotic, anti edematous, anti-inflammatory and fibrinolytic activities in vitro and in vivo. Even though being used as traditional medicine and there was important information about A. comosus but for research developments still required more information about this plant. This review verified the use of A. comosus in traditional medicine, pharmacology activities...
and explored on phytochemical compounds.

**MATERIALS AND METHODS**

Data and information in this article were collected from scientific literature databases such as Science Direct, Google Scholar, Scopus and PubMed.

**RESULTS AND DISCUSSION**

**Botanical Aspect**

In the worldwide pineapple in tropical regions have around 30 cultivars of which are cultivated in distinct environmental areas. Based on leaves and fruit characterisation A. comosus cultivars are categorised into five classes, named as “Red Spanish”, “Pernambuco” (Abacaxi), “Queen”, “Smooth Cayenne”, and “Perolera” or “Motilona”. Adult plants of the cultivar “Queen” and “Smooth Cayenne” respectively are up to 1 m and 1.5 m high, and had 0.5 m, 1 m wide (Guang et al., 2016). Generally in appearance, A. comosus has a spiral morphology due to the arrangement of the leaves, waxy leaves, short and sturdy stem. When preparing its fruit, it usually produces up to 200 flowers, and after that individual fruits of the flowers join together to create a pineapple. When the first fruit is produced, suckers are formed in the leaves axils of the main stem. After a year of growth, the axis lengthens and thickens, and the stem grows into a spike-like inflorescence up to 15 cm long. Flower colours depending on variety, from lavender through light purple to red, formed on an inflorescence at the apex of the stem. A. comosus can grow around at a temperature of 18–32 °C, most productive under dry environments, as it can be planted in the soil that does not require a lot of water, it requires as much as 5 cm³ water per month from irrigation or rain, during autumn and spring an average rainfall is of 115 cm.

Most pineapples are cultivated on hillsides, and it thrives well when grown on a north-easterly aspect where they receive the maximum amount of sunlight and warmth. A. comosus require sandy soils with high organic matter and having a pH range from 4.5 to 6.5, with good water drainage makes soil perfect for A. comosus production, therefore provide good water drainage system. Around 18 to 24 months period is usually required from growing to harvest. A. comosus can be harvested throughout the year during flowering (Morton and Dowling, 2013)

**Traditional Uses**

Ananas comosus L. Merr. ItIs the most edible member of the family Bromeliaceae, this plant is used in folk remedies for a digestive disorder, and it’s diuretic property also it has been reported to act as an abortifacient. However, no scientific evidence supported the efficacy of A. comosus in inducing abortion (Yabesh et al., 2014). A. comosus is usually used as food and juice of ripe fruit assumed can be used as antiscorbuticand diaphoresis (Kalaiselvi et al., 2012). The root and fruit either eaten or utilised topically were used as an anti-inflammatory and as a proteolytic agent. In the Philippine, this plant traditionally was utilised as antihelminthic, and a decoction of A. comosus root used to treat diarrhoea. The fruit had the potential in promoting digestion as well as treating throat problems and its activityto prevent heart disease. It was also used as a natural diuretic in bronchial tissues to clear mucus (Hossain and Rahman, 2011). In China, cortex of A. comosus potential as antidiarreal agents, alexipharmic and antitussive; and leaves of A. comosus were usually applied as an antidispepsia or antidiarrheal agent in Chinese Traditional Medicine. A. comosus is one of the tropical fruits in Indonesia and known as nanas among Indonesian, which used to treat cough, maintain blood pressure and boost immunity. Subang, Bogor, Riau, Palembang and Blitar, the primary producer in Indonesia, is supplying A. comosus. The usage of A. comosus as traditional medicine will be presented in Table 1.

**Phytochemical Compounds**

Phytochemicals are naturally occurring in plants part such as leaves, fruit, roots, bark, peel, flowers, a stem that have defence mechanism and protect from various diseases. Phytochemicals compounds are primary metabolites such as proteins and carbohydrateand secondary metabolites such as alkaloid, flavonoids, phenolic compound, saponin, steroid and terpenoid (Kalaiselvi et al., 2012). A phytochemical constituent from a crude extract of leaves, stem and fruit of A. comosus showed the presence of such as terpenoids, flavonoids, amino acid, protein, cardiac glycosides, phytosterols, carbohydrate, alkaloids, and saponins. Fresh pineapple fruit contained many fibre, carbohydrate and some minerals especially calcium, potassium, phosphorus, iron and sodium, also included copper, its contribution in the absorption of iron, regulates blood pressure and heart rate. It also contained some vitamins including ascorbic acid, folic acid, pyridoxine, pantothenic acid, niacin, riboflavin, thiamine, and retinol. The antioxidant activities related to the plants genetic and environmental factors, and the nutritional level is affected by diverse factors such as maturity stage, climatic, handling, varieties, and soil. Previous studies also said that A. comosus had the potential to be a good source of antioxidant, because in this plant presence of flavonoids, ascorbic acid and phenolic
Table 1: Traditional uses of Ananas comosus L. Merr.

| A. comosus Plant Part | Traditional Uses                                      | References               |
|-----------------------|--------------------------------------------------------|--------------------------|
| Peel                  | Antirheumatic activity, antioxidative, anti-bacterial   | (Putri et al., 2018)    |
| Fruit                 | Fermented fruit in therapeutic for cancer, fruit residue as nutraceutical against diabetes, reduce pain after surgery and sport injuries | (Riya et al., 2014)  |
| Leaves                | Antidiabetic activity, leaves juice as purgative, emmenogogue, and vermifuge | (Kalpana et al., 2014) |

Table 2: Volatile components found in A. comosus

| Volatile components                  | Odour description       | References               |
|--------------------------------------|-------------------------|--------------------------|
| Methyl-3-(methylthio) propanoate*     | Pineapple-like          | (Teai et al., 2001)     |
| Ethyl-2methylbutanoate*              |                         | (Teai et al., 2001)     |
| Ethyl acetate*                       |                         | (Umano et al., 1992)    |
| Ethyl-3-(methylthio) propanoate      | Fruity, pineapple-like  | (Teai et al., 2001)     |
| 2,5-dimethyl-4-hydroxy 3-(2H) furanone | Burnt pineapple       | (Umano et al., 1992)    |
| Butane 2, 3 diol diacetate           | Honey-like              | (Umano et al., 1992)    |

Table 3: Pharmacological activities of Ananas comosus L. Merr.

| Sample of Ananas comosus              | Pharmacological Activities                                      | References               |
|---------------------------------------|----------------------------------------------------------------|--------------------------|
| Methanolic fruit peel extract         | Antirheumatoid, antioxidant and antibacterial activities       | (Poadang et al., 2017)   |
| Fermented fruit extracts              | Candidate in therapeutic approaches for cancer                 | (Rashad et al., 2015)    |
| Leaves extract                        | Antidiabetic activity using streptozotocin (STZ) induced diabetic rat method | (Kalpana et al., 2014)   |
| Fruit residue                         | Nutraceutical for diabetes and related problems                | (Romelle et al., 2016)   |
| Ethyl acetate fraction fruit          | Tocolytic activity on rat and human arteri                    | (Monji et al., 2018)     |

Compounds (Hossain and Rahman, 2011), flavones-3-ol, quercetin, flavones (Mhatre et al., 2009), ferulic acid and p-coumaric acid. Both A. comosus rind and core presented β-carotene and L-ascorbic acid, but lutein and α-carotene were found only in A. comosus rind (Freitas et al., 2015). In dry methanol peel extract of A. comosus had major polyphenolic compounds were catechin, epicatechin, gallic acid and ferulic acid. Based on previous research, individual phenolics in A. comosus were myricetin, p-hydroxybenzoic acid, p-hydroxybenzoic aldehyde, syringic acid, tannic acid, sinapic acid, caffeic acid, salicylic acid and trans-cinnamic acid. Distinct and pleasant flavour make A. comosus popular fruit because there are volatile components. More than 280 compounds have been found among the volatiles of A. comosus.

Volatile compounds in A. comosus will be expressed in Table 2. The sugar in A. comosus such as glucose, sucrose, and fructose. The primary non-volatile organic acids at this plant were malic and citric. Stem and full-grown fruit contained proteolytic enzyme, bromelain, which belongs to the group of endopeptidases, also in this plant there was melatonin in as well.
The amount of bromelain found in fruit A. comosus much less than in the stem, and the highest was seen at the top of the fruit but fruit bromelain had high proteolytic activity compared to stem bromelain. Bromelain activity showed higher during fruit development than the ripening stage parallel with the total protein content. The enzymatic action of these enzymes in the range of pH 5.5-8. Another enzyme was polyphenol oxidase (PPO), at harvest time, its activity was usually low, and the activity will be higher after inducing by chilling stress. PPO activity varied among distinct parts of the collected fruit. The skin and crown leaves gave higher levels than the pulp of the fruit. Bromelain was a mixture of diverse thiol endopeptidases, cellulases, glycoproteins, carbohydrates, phosphatases, glucosidase, peroxidases and few protease inhibitors (Difonzo et al., 2019).

Pharmacological Activities

The previous study demonstrated that A. comosus extracts contained phenolics and flavonoids compounds which can act as an antioxidant (Bamidele and Fasogbon, 2017), antibacterial (Dutta and Bhat-tacharyya, 2013), and anti-inflammatory. General pharmacological uses for A. comosus as can be seen inTable 3.

Antimicrobial and Nontoxic Activities

The water extract of the crown leaves of A. comosus expressed nuclease, peroxidase along with considerable antibacterial, gelatinolytic, collagenase, nonspecific proteolytic, anti-fungal, acid and alkaline phosphatase, and fibrinolytic activities. Leaves extract A. comosus acta antibacterial within minimum inhibitory concentration (MIC) varied from 1.65 to 4.95 mg/ml against Bacillus subtilis, Candida albicans, Escherichia coli and Staphylococcus aureus (Dutta and Bhattacharyya, 2013). Based on previous research, it was supposed that bromelain and saponin were important components against Gram-negative, meanwhile flavonoids and polyphenols potent to inhibit Gram-positive bacteria, which work in the peptidoglycan layer. Bromelain was predicted causing injury and cell death by inducing protein breakdown in the bacterial membrane, while saponin worked by increasing permeability of the membrane of a bacterial cell and quickly enter the cell, after that influence the cell metabolism and denatures proteins on the cell membrane. Therefore, lysis will occur in the cell membrane. Pineapple extract at a concentration of 0.2 g/mleliminated non-Multidrug Resistant Pseudomonas aeruginosa, exhibited antibacterial activity against Streptococcus pneumoniae and Staphylococcus aureus. The chloroform and acetone extract of A. comosus gave antimicrobial activity against Candida albicans, candida tropicalis, Candida glabrata, Cryptococcus luteolus and candida rubrum. Acute toxicity testing indicated that leaves extract up to 5000 mg/kg in rats by oral administration did not present death or toxicity. Therefore it can be concluded that nontoxic extract (Ajibade et al., 2015).

Antioxidant Activities

Previous research expressed that antioxidant activity may be related to anthocyanins, cate-chins, isoflavones, flavones, and other phenolics compounds (Mhatre et al., 2009). The antioxidant activity was produced by different mechanisms which were free radical scavenging, catalase activity increase, oxidative enzymes inhibition and metal chelation. Based on (Mhatre et al., 2009), the methanol extracts of A. comosus express the highest antioxidant activity in DPPH assay (1933.0 ± 9.1% equivalent of ascorbic acid). Previous research stated that combination of bromelain and antibiotic therapy gave more effective in cutaneous Staphylococcus infection, pneumonia, bronchitis, thrombophlebitis, pyelonephritis, cellulitis in perirectal and rectal abscesses, urinary tract infections and sinusitis. Bromelain, trypsin, rutin and antibiotics in combination had been given as adjuvant therapy for children with sepsis. Also, combination bromelain, ox bile, and pancreatin were sufficient to reduce faeces fat excretion in a patient with pancreatic steatorrhea, improvement in pain, flatulence and faeces frequency (Pellicano et al., 2009).

Anticancer Activities

The ethanolic peel extract of A. comosus (250 mg/kg body weight) for 30 days orally had activities to lower lipid peroxidation, and tumour weight in breast tissue expressed near to normal levels. Based on the experiments, it can be predicted that A.comosus had anti-breast cancer potential. Bromelain can inhibit nuclear factor-KB (NF-KB) translocation via G2/M arrest to apoptosis in human epidermoid carcinoma and melanoma cells. Bromelain exposed to selectively induce apoptosis in tumour cells by upregulation of p53 expression and initiation of the mitochondrial apoptotic pathway by increasing Bax expression and cytochrome c release. Also, bromelain work significantly decreased the evolution of gastric carcinoma Kato-III cell lines Báez et al. (2007)

Anti-Inflammatory Activities

A. comosus extracted exhibited anti-inflammatory activity in the gastrointestinal tract and had good influence to treat ulcerous colitis and Crohn's dis-
ease. The research revealed that pineapple peel extract had protective effects on brain tissue to prohibit an alcohol-induced change in phospholipids and lipid peroxidation (Erukainure et al., 2011). Fruit of A. comosus had an impact on inhibition and augmentation of uterine contractility with an objective mechanism in a 5-HT pathway. Bromelain anti-inflammatory activity works in a way downregulates COX-2 and PGE-2 expression levels in murine microglial cells and human monocytic leukaemia cell lines. In mouse macrophage and human peripheral blood mononuclear cells (PBMC), bromelainactivated the inflammatory mediators, including interleukin (IL), ‐1β, IL-6, interferon (INF)‐γ and tumour necrosis factor (TNF)‐α.

Furthermore, in patients with osteomyelofibrosis and rheumatoid arthritis, bromelain modulated the expression of transforming growth factor (TGF)‐β, which is a primary regulator of inflammation. When bromelain was given to the murine model of acute asthma, this enzyme worked to decrease airway reactivity and sensitivity to irritants, reduced markers of lung inflammation and moderated aspects of local airway immunity. In a rheumatoid arthritis rat model, a combination of bromelain and cyclosporine could reduce inflammation and arthritis (Secor et al., 2008).

Hypolipidemic Activities

Ethanolic leaves extract of Ananas comosus had a hypolipidemic effect, that related to inhibiting HMG CoA reductase and from there selectively increased plasma lipoprotein lipase activity (Xie et al., 2007).

Anthelmintic Activities

Leaves of A. comosus has been traditionally applied as oral anthelmintic medicine in North-East India. Anthelmintic activity of A. comosus leaves extract was investigated using adult Indian earthworms (Pheretima Posthuma) and exposed that there was dose-dependent increase with the time taken paralysis and time taken for death as parameters (Kataki, 2010). In vitro evidence showed that bromelain used as anthelmintic activities against the gastrointestinal nematodes, Trichuris muris and Heligmosomoides polygyrus.

CONCLUSIONS

This literature review aimed to report traditional uses, chemical compounds and pharmacological activities of the Ananas comosus L. Merr. This plant is a tropical fruit, that is consumed as fruit, food and traditional medicine. Based on research, there are such a lot of phytochemical compounds in Ananas comosus L. Merr, such as flavonoids, ascorbic acid and phenolic compounds. Most of the studies in pharmacological activities of A. comosus were limited to in vitro experiment.

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Conflict of Interest

Authors declare no conflict of interest.

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