Effects of selected plants on the survival of *Staphylococcus aureus*

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This chapter describes the impact of plants and selected phytochemicals from different plants on survival of *Staphylococcus aureus*. Plants that may be used in the food industry were chosen. This study presents brief characteristics of staphylococci and compounds of biostatic character present in plants. The subject of assessment was the inhibitory activity of phytochemicals in relation to staphylococci depending on the way of tissue preparation. Inhibition of staphylococci was shown with regard to the parts of plants, from which substances of biocide character were isolated. This paper also describes studies connected with *Staphylococcus aureus* inhibition by herbs, mixtures of fruit, succulents, and extracts from the tubers and seeds of various plants. An attempt was made to take into account the influence of the type and maceration level of plant tissues and the way of extraction of phytochemicals on staphylococci inhibition. The subject of assessment was the influence of the type of plant tissue preservation on their biostatic and biocidal activity in relation to staphylococci. The possibilities of application of plant macerates, plant sprays and phytochemicals in the process of production of safe food is also described in this paper.

**Keywords**: plants, phytochemical, phytoncides, *Staphylococcus aureus*, biostatic activity

*Staphylococcus aureus* is a gram-positive coccus forming spherical to ovoid cells about 1 µm diameter with tendency to form cluster cells. Staphylococci are coagulase–positive, oxidase–negative, facultative anaerobes but grow best in aerobic conditions. The bacterium is non-motile. Most strains grow well at temperature between 35–40.

Staphylococci have the ability to grow in low as well as in high temperatures in 7 and in 48 [1]. Heat resistance in model conditions is not high. Depending on the cell strain they are inactivated at 54 or 60°C. Thermal stability of staphylococci cells varies, depending on the type of food in which they appear [2]. The value of decimal reduction for milk is at temperature of 72°C in 4,1 seconds. Numerous strains synthesize enterotoxins marked with letters from A to J. Enterotoxins are single–chain proteins with a molecular weight from 26 to 30 KDa [1-3]. Thermal stability of enterotoxins is exceptionally high. For the SEA enterotoxin the inactivation temperature is 100°C and for SEB and SEC yet 120°C in time from 26 to 30 minutes [2].

Staphylococci enterotoxins are resistant to proteolytic enzymes such as pepsin, tripsin, chemotrypsin, rennin and papain. The ability to produce toxins was observed in the following temperature range 10-45 at pH from 4,8 to 9.0. Staphylococci are halotolerant organisms therefore, both the ability to survive in the environment and the production of enterotoxins may occur at 20% NaCl [3].

It grows very well in media containing 5-7% and when water activity value is ranking 0,86.

In environments with the lowest possible value aw the generation time of these micro-organisms is longer than 5 h. More than 107 cfu/g staphylococci present in food can cause synthesis 1 µg of SEA by *Staphylococcus aureus*. The number of viable staphylococci isolated from food ranged from none to 1,5*1010 jtk/g. The structure of distribution of staphylococci in food indicates that meat and poultry or their products were vehicle in 75% of incidents. Seafood accounted for 7% and dairy foods for 8%. Most contamination occurred from hospital infection via wounds and mucous membranes. Methicillin –resistant *Staphylococcus aureus* is a major cause of them.

Staphylococci resistance to antibiotics has resulted in the emergence of strains of *Staphylococcus* called MDR (Multidrug Resistance). Their presence is caused by inhibition of NorA efflux mechanisms [4]. However, there are many substances of plant origin as phytoncides, which express diverse biostatic activity in relation to staphylococci [5-23].

Phytochemicals and phytoncides are a large group of compounds found in different plant species. Numerous plants may contain one or many of these phytochemicals placed in seeds, fruit, leaves, stems, flowers, tubers. Phytoncides show diverse chemical definition - compounds that belong to them – can be classified as: organic acids, phenols, alkaloids, terpenes, polyketones, polyenes, sulfur products, flavonoids.

Important for food purposes are organic acids - some substances isolated from fruits like citric acid present in many citrus fruits.

Among acids the citric acid – shows biostatic influence on staphylococci culture and clinical researches established that for inhibition of *S. aureus* resistant to ampicillin, chloramphenicol and other antibiotics is needed 900 µg/mL [24]. Other acids such as sorbus acid – from ash fruit shows particularly strong activity in acidic conditions (3 < pH < 6). The mechanism of its action relies on inhibiting enzymes activity of micro-organisms such as: dehydrogenases, catalases, peroxidases.
One of the major acids is benzoic acid that occurs in most fruits, e.g. in blackberries and cranberry and also in cinnamon, cloves and mushrooms. Benzoic acid shows strong antiseptic activity and antagonism against yeasts in acidic environment at pH < 5.

Sulfur compounds - oils from Allium sativa and Allium cepa are rich in sulfur containing allicin. In literature data its known substances are strongly antimicrobial. A large number of these compounds can be isolated from garlic where there are such substances, as for example methyl alliin, propyl alliin, propenyl alliin and S-propenyl-cysteine sulfoxide and also dipeptides and essential oil.

It also consists of n-propyl disulfide and trisulfide, propyl-trisulfonium and dimethyl-thiophene.

The main component of horseradish, responsible for its medicinal properties, is syringin. In terms of chemistry it is allil-o-glucosinolate. As a result of root damage tissues sinigrin, under the influence of the enzyme, is hydrolyzed and dissolves to glucose and allyl isothiocyanate (mustard oil).

Alkaloids – are organic nitrogenous substances which are bitter and insoluble in water. Coffee beans contain significant concentration of alkaloids. There is little number of researches on bacteriostatic properties of substances present in coffee beans.

Phenols are a group of compounds present in a large group of plants. To the most popular among 8,000 of them belong eugenol, carvacrol, thymol.

Tannins are aromatic acidic glycosides, water-soluble poly-phenols that are commonly found in some plants. Significant amounts of tannins appear in tea, grapes, strawberries and persimmon [25,26].

In tea leaves there are different concentrations of these compounds depending on the production method of tea, although their concentrations were found in green tea [27]. Tannins have the ability to inactivate cell adhesion molecules, enzymes and proteins involved in transport, also have the ability to react with polysaccharides. These of their properties may cause intense inhibition of staphylococci cells division [28]. Bacteriostatic and biocidal activity of tannins was described by some investigators [29,30,31]. Tea leaves contain tannins of high bacteriostatic and antifungal performance.

The effect of activity of catechins isolated from green tea was raised in literature, indicating their high biocidal effect [32, 33]. Catechins isolated from leaves of tea also have significant impact on Shigella [34]. Tannic acid occurring in the leaves has the ability to inhibit Staphylococcus aureus MSSA and MRSA at a concentration of 250-1000 mg mL [27]. The research shows that the aqueous extracts of green tea are able to reverse beta-lactam resistance in methicillin-resistant Staphylococcus aureus (MRSA) [35]. To substances of antioxidant and biostatic properties belong also catechol, cumarin, syringic and vanillic – phenolic compounds of significant activity in inhibition of development of bacteria isolated from orange peel [36]. Significant concentration of phenolic compounds are also present in the herb tea-water extract.

Most of these compounds were found in extracts of Oolong tea, Arabia jasmine and guava [37]. Effective impact against the development of population of Staphylococcus aureus showed gallic acid present in plants [38]. To phenolic compounds belong also flavonoids being one of the components of tomatoes, onions and tea. Flavonoids isolated from the seeds and pulp of grapefruit show strong activity against number of bacteria occurring in gastrointestinal tract such as Prevotella, Porphyromonas, Bacteroides, Fusobacterium, Veillonella, Peptostreptococcus, Actinomyces, Propionibacterium, Eubacterium.

It was found that adding the grapefruit extract to the cultures of anaerobic bacteria mentioned above inhibits their growth. Some data shows that the diterpenes present in plants are responsible for inhibition of staphylococci [39]. Estevaz - Brown and et al. (1994) have proven effective impact of polyamine on bacteria [40]. It was found that polyamine derivative shows high degree of effective inhibition of Staphylococcus aureus, Bacillus subtilis and yeasts.

Glycosides numerous plant chemicals contain a carbohydrate residue usually have a characteristic odor of bitter almonds. To the group of glycosides belong saponins included for example in soya and plant sprouts. On the base of the study it was found that biostatic activity of saponins and alkaloids is strongly dependent on the type of plant from which they are isolated.

Some of the saponins show lower biostatic activity towards Staphylococci compared with steroids, Tannic acid, flavonoids and glycosides [20]. Extract of saponin isolated from soya is able to inhibit the growth of Staphylococcus aureus at MIC of 25-50 μg/ML [18]. Anthraquinone glycosides are essential active compounds of antimicroorganisms activity properties.

Anthraquinones can be isolated from succulent plant tissues such as aloe and to them belong aloin, barbaloin, isobarbaloin, anthranol, cinnamic acid ester, emodin. Aloin – 10B –glucopyranosyl 1,8-dihydroxy-3-hydroxymethyl-9(10H) anthracenone is a substance of significant biostatic meaning. However, dynamics of microorganisms inhibition strongly depends on the way of leaves tissue preparation. The researches reveal that 90% gel Aloe vera was effective against Staphylococcus aureus. Its inhibitory activity was also stated in relation to other bacteria such as Escherichia coli, Bacillus subtilis Streptococcus pyogenes i Streptococcus agalactiae [41]. Later researches revealed biostatic effects of Aloe vera extracts even at 60% concentration [42]. Inhibition of development was also observed in relation to populations of such bacteria as Citrobacter, Enterobacter coloace, Pseudomonas aeruginosa, Streptococcus pyogenes i Streptococcus agalactiae.
That concentration was not effective in relation to Staphylococcus aureus, Escherichia coli and Bacillus subtilis. Fresh leaves extracts tested in relation to fungi revealed inhibition of development of Aspergillus niger, Cladosporium herbarum or Fusarium moniliforme [43]. In case of antifungal effectiveness of aloe extracts, differences depending on the aloe species used for testing, were not observed. Comparison of antiseptic activity carried out on the clinical strains of staphylococci showed that the ethanolic extract of Aloe barbadensis also exhibited high biostatic activity against S. aureus [44]. Aqueous extracts of plants were not effective in these bacteria inhibition.

The concentration of phytoncides in plant tissues varies depending on the species of plants and parts from which they are extracted. This is especially important in the case of herbs [16].

Activity of phytoncides also depends on the way of material preparation. The example can be varied aloe activity depending on the degree of tissue maceration or type of extraction and processing of the leaves. Biostatic effect is different when using pulp or homogenate and when using leaves without skin [45]. The Enoth-Arthur (2003) test results concerning the impact of fresh aloe juice on Staphylococcus aureus cells isolated from skin infections confirm biostatic influence of fresh tissue on tested micro-organism [46]. Agarry et al. (2005) in their researches regarding the comparison of antimicrobial activity of gel and extract from the leaves of Aloe barbadensis, showed that both forms possess significant inhibitory properties in relation to staphylococci [47]. Moreover, they observed that despite the presence of components of biostatic nature in the extract and gel, the form of processing affects the degree of inhibition of micro-organisms.

A study concerning biostatic characteristics of various herbs, fruit and vegetables confirmed susceptibility of staphylococci on their activity [48]. The presence of phytoncides in different chemical construction was the reason for different dynamics in reduction of the number of bacteria. Biostatic activity in relation to the micro-organism depended on: how the plants were shaped before their interactions with bacteria [48,49]. Aqueous herbs homogenates allowed extractions of only minor amount of compounds present in the leaves. Homogenization of basil leaves caused partial release of aromatic compound called methyl p-allilophenol, which can effectively reduce the size of the population of staphylococci [48]. Salvia in the form of infusion contains significant quantities of terpenic compounds and therefore numerous researchers indicate it as a herb of significant biostatic activity in relation to bacteria [50].

Biostatic characteristics of 2-methyl-5 isoproplyphenol present in oregano were repeatedly tested and literature data attest the importance of significant biostatic value in this substance, both in relation to bacteria, and fungi [51,52,53]. It has been proven that the compound inhibits such micro-organisms as Listeria monocytogenes, Staphylococcus aureus, Salmonella [52]. The data shows that thymol present in oregano shows antibacterial activity not only in relation to S. aureus, but also to Staphylococcus epidermidis [54].
Table 1 Inhibition of *Staphylococcus aureus* by selected plants

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Additive type</th>
<th>Conditions</th>
<th>Change amount of population Log CFU/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregano</td>
<td>Leaves</td>
<td>Aqueous extract, incubation time 2h</td>
<td>0.56</td>
</tr>
<tr>
<td>Mint</td>
<td>Homogenised with isotonic fluid</td>
<td>Aqueous extract, incubation time 2h</td>
<td>0.7</td>
</tr>
<tr>
<td>Basil</td>
<td>Homogenised with isotonic fluid</td>
<td>Aqueous extract, incubation time 2h</td>
<td>1.14</td>
</tr>
<tr>
<td>Rosemary</td>
<td>Homogenised with isotonic fluid</td>
<td>Aqueous extract, incubation time 2h</td>
<td>0.92</td>
</tr>
<tr>
<td>Tomato</td>
<td>Tissue macerate</td>
<td>Incubation time 2h</td>
<td>1.22</td>
</tr>
<tr>
<td>Onion</td>
<td>Tissue macerate</td>
<td>Incubation time 2h</td>
<td>0.4</td>
</tr>
<tr>
<td>Lemon</td>
<td>Juice</td>
<td>Solution - 10%</td>
<td>1.85</td>
</tr>
<tr>
<td>Orange</td>
<td>Juice</td>
<td>Solution - 10%</td>
<td>1.0</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>Juice</td>
<td>Solution - 10%</td>
<td>0.4</td>
</tr>
<tr>
<td>Red Grapefruit</td>
<td>Tissue and seeds macerate</td>
<td>Solution - 1% , incubation time 30 min and 2 h</td>
<td>0.57-0.77</td>
</tr>
<tr>
<td>Yellow Grapefruit</td>
<td>Tissue and seeds macerate</td>
<td>Solution - 1% , incubation time 30 min and 2 h</td>
<td>0-1.26</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>Seeds extract – pharmaceutical preparation</td>
<td>Solution - 10%</td>
<td>7.76-8.23</td>
</tr>
<tr>
<td>Aloe</td>
<td>Macerate with skin</td>
<td>Model conditions</td>
<td>0.51</td>
</tr>
<tr>
<td>Aloe</td>
<td>Macerate without skin</td>
<td>Model conditions</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Juice aerosol</td>
<td>Food 1 cm³/cm² after storage after 2 and 7 days at 4°C</td>
<td>After 2 days 0.35 After 7 days at 0.46</td>
</tr>
<tr>
<td></td>
<td>10% aqueous solution</td>
<td>Food at pH= 4.8</td>
<td>0.78</td>
</tr>
<tr>
<td>Sorbus aucuparia</td>
<td>Homogenised after tissue maceration</td>
<td>Incubation time-0.5 h</td>
<td>+0.12</td>
</tr>
<tr>
<td>Kalanchoe</td>
<td>Homogenizat</td>
<td>After 24 and 48 h</td>
<td>0.1</td>
</tr>
<tr>
<td>White tea</td>
<td>Aqueous infusion</td>
<td>Aqueous solution at a temperature of 100°C, Time incubation - 0.5 h and 2 h</td>
<td>6.34 and 7.0</td>
</tr>
<tr>
<td>Black Tea</td>
<td>Aqueous infusion</td>
<td>Incubation time 0.5 h, 2 h</td>
<td>5.57 and 6.0</td>
</tr>
<tr>
<td>Green Tea</td>
<td>Aqueous infusion</td>
<td>Incubation time 0.5 h, 2 h</td>
<td>5.47 and 4.77</td>
</tr>
<tr>
<td>Red Tea</td>
<td>Aqueous infusion</td>
<td>Incubation time 0.5 h, 2 h</td>
<td>6.47 and 6.64</td>
</tr>
<tr>
<td>Tea + Kalanchoe</td>
<td>Aqueous infusion</td>
<td>2h depending on concentration</td>
<td>3.19 and 4.02</td>
</tr>
<tr>
<td>Tea + Kalanchoe + lemon</td>
<td>Aqueous infusion</td>
<td>2h depending on concentration</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Source: [12, 55,56, 57, 58, 59].

In model research high degree of inhibition of tested bacteria by oregano in Table 1 was not observed. According to studies results conducted by different authors thymol does not work as efficiently on staphylococci, as e.g., menthol or carvacrol [60]. It is likely that the simultaneous presence of thymol and 2-methyl-5 isopropylphenol do not necessarily have the same inhibitory effect as when these compounds occur in plants separately.

Mint consists of such compounds as menthol, menthane 3-on and mentho-furan. Inhibition of staphylococci development under the influence of mint solution was, however, observed only after 2 hours of incubation, which may indicate poor sensitivity of staphylococci to these compounds or low interaction dynamics [48]. Essential oils extracted from herbs reveal varied effectiveness in inhibition of staphylococci growth. In model conditions essential oils of mint necessary for staphylococci inhibition are 1% v/v and in case of basil, up to 2% v/v. The presence of these substances present in essential oils from oregano, yet worked effectively at 0.12% concentration level [7].

Different MIC values of essential oils from herbs indicate that the extraction of substances from plants using alcohol gives, as a result, compounds of different spectrum of antimicrobial action [16]. Researches were carried with the use of *Staphylococcus aureus DSM 20231*. This strain of staphylococci revealed low sensitivity to phytochemicals from
Biostatic activity of plants depends on water content in their tissues and the consistency of that tissue. Lower mint. Relatively high degree of staphylococci reduction was observed in the presence of rosemary and basil [48].

In case of cucumbers, the reduction of quantity of the bacteria population amounted to 0,4 log cfu/cm³ after 2 h. The most dynamic content, degree of tissue maceration and the way of phytoncides extraction. Among the tested herbs, basil showed the such as allyl of isocyanate in relation to a number of pathogenic bacteria, including [66]. Shofran et al. (1998) observed a line bacteriostatic activity of certain substances isolated from crucifer plants, onions causes, regardless of the concentration, that the number of staphylococci increases by 4 logarithmic cycles.

Flavonoids present in grapefruit seeds constitute essential substances of a preparation of biocidal, for staphylococci, effect [59]. However, already macerate of the fruit and seeds tissues of grapefruit possesses biostatic activity. The level of reduction of staphylococci depends on the concentration of added pulp and on grapefruit species in Table 1. It has been shown that 1% macerate of tissue of white grapefruit reduces bacteria by 1,26 log cfu/g and of red grapefruit only by 0,77 log cfu/g after two hours of contact with Staphylococcus (tab. 1). In model conditions high degree of biostatic activity of allyl was observed [8,9]. An example of the influence of the tissue treatment on the effectiveness of phytochemical is to assess the reduction in number of Staphylococcus aureus by released in the preparation process tiosulphonates, garlic oil esters and allicins. In each case, the value of MIC is different as follows: 80, 20 5 µg/mL [9]. The MIC value needed for Staphylococcus aureus inhibition depends also on the tested strain of staphylococci and extracted phytoncides fractions. For Staphylococcus aureus IFO14462 bacteria inhibition was observed after exceeding 70 µg/mL [8].

In the case of phytoncides released from tubers (onion and garlic) heat treatment before testing the strength of bacteriostatic impact affects the level of staphylococci reduction. Kyung et al. (2002) demonstrated that fresh onion extract subjected to 121°C [65]. heating, affects the activity of allilin contained in tuber. At total allilin thermally degraded inhibition of growth of Staphylococcus aureus is observed when the concentration of added onion extract exceeds 15%. The antibacterial activity of heated garlic increased towards 45 min of heating. However, blanching the onions causes, regardless of the concentration, that the number of staphylococci increases by 4 logarithmic cycles [65]. Shofran et al. (1998) observed a decline bacteriostatic activity of certain substances isolated from crucifer plants, such as allyl of isocyanate in relation to a number of pathogenic bacteria, including Staphylococcus aureus [66].

Staphylococci inhibition dynamics varies depending on the time of interacting with the plant, the level of water content, degree of tissue maceration and the way of phytoncides extraction. Among the tested herbs, basil showed the most dynamic biostatic activity reflected by the highest reduction of staphylococci after 30 minutes of common incubation. In comparison with other tested plants, low degree of staphylococci reduction after 2 hours was noted for mint. Relatively high degree of staphylococci reduction was observed in the presence of rosemary and basil [48].

Biostatic activity of plants depends on water content in their tissues and the consistency of that tissue. Lower effectiveness in inhibition of growth of staphylococci population was stated in case of onions after 30 minutes, than in case of cucumbers. The reduction of quantity of the bacteria population amounted to 0, 4 log cfu/cm³ after 2 h. The researches show that in case of cucumbers the specific fraction of amine is responsible for the inhibitory effect of Staphylococcus aureus growth [67].

Among the citrus fruit significant biostatic properties had lemon, which decreased the population of staphylococci by 1, 85 cfu/cm³ after 2 hours of common incubation. A half-hour interaction 10% of other fruit juices with staphylococci culture caused reduction in the number of bacteria from 0.4 to 1.0 cfu/g in Table 1. Low biostatic activity towards staphylococci has been recorded for grapefruit juice. Inhibition of staphylococci population occurred at a speed of 0.2 log cfu/cm³ * h⁻¹. Observed dynamics of staphylococci reduction in the presence of fresh grapefruit juice was lower than in case of other tested fruit juices and vegetable tissues [48]. Inhibition of Staphylococcus aureus population in the presence of 10% grapefruit juice required more than 9 times longer inhibition time in comparison to the effect achieved by lemons [48].

Low level in number changes in the presence of staphylococci macerate by onion macerate was not similar to that observed in case when garlic was used. Researches on the comparison of biostatic activity of aloe tissues and fruit of plants of relatively low water content (Sorbus aucuparia) showed that inhibition of the development of staphylococci...
depends on the conditions in which the tests were carried. Sensitivity of staphylococci to aloe and *Sorbus aucuparia* separately and their mixture was different depending on the conditions in which the test was performed than interaction with bacteria [56].

As a result of the studies it was found that 10% of the additive of aloe mixture and 10% *Sorbi fructus* do not reduce significantly staphylococci population in the process of food production at pH < 5.0 [56]. In lactic acid cheese curd at the time of pressing and drying staphylococci at a level 1.0x10^2 cfu/g were found. The level of these micro-organisms in the warmed and pressed curd containing a mixture of *Sorbus aucuparia* and aloe remained unchanged.

In parallel with the research concerning behaviour of additives in lactic acid cheese curd, research in a model system were carried. They allowed to note that the impact of *Sorbus aucuparia* preparation on staphylococci increase was insignificant in Table 1.

Model research revealed the lack of ability to use the additive of aloe and fruit extract from *Sorbus aucuparia* mixture in order to reduce the population of enterococci and yeasts. Slight effects of staphylococci inhibition was observed when applying a mixture of plants for the production of lactic acid cheese that are produced from raw material of little re-infection ability.

Studies on biostatic properties of fruit confirmed different contents of phytoncides with different strength of the inhibitory impact, that depended on the parts of plants. It was found that grains and seeds indicate low biostatic activity before grinding due to compact structure of tissues. Therefore, the MIC in case of green coffee beans is high and comes up to 0,125mg/mL [21].

Better biostatic effect was observed during the reaction between the pulp and grapefruit pips macerate [59]. In case of staphylococci reduction of population even from 0,77 to 1,26 log cfu/cm^2^ was observed, depending on the grapefruit species (Table 1). Important role is assigned to phenolic compounds in the process of inhibition of bacteria population [68]. The literature data shows significant inhibitory activity of citric extract, but up till now researches has been carried out only in relation to fungi, *Bacillus sp.*, and LAB [69].

Grapefruit seed preparation showed very significant biocidal activity in relation to the cells of *Staphylococcus aureus* ATCC 25923. Grapefruit seed extract contains, among other, such flavonoids and glycosides as: naringenin rutoside, quercetin, kaempferol, apigenin rutoside, hesperidin, nobiletin or dihydrokaempferol. Combination of these compounds has stronger inhibitory effect than organic acids present in grapefruit pulp what explains the biocidal effect of pips extracts.

In food manufacturing essential oils are not as important as in medicine. Tea tree oil contains substances which biostatic impact on micro-organisms is different in relation to fungi and bacteria. Not less than 0,5 to 1,25 of tea tree extract is needed to gain first biostatic effect in relation to *Staphylococcus aureus* [70].

The data presented by Hammer et al. (1999) states that for the inhibition of *Staphylococcus aureus* the minimum inhibitory concentration MIC for the essential oils from lemon is 2% v/v [7].

An important element of biological activity of phytoncides present in dried plants is the impact of the temperature during the preparation of water-based infusions. There is little data on biostatic properties of aqueous tea infusions. A significant influence of aqueous infusions of various teas on *Staphylococcus aureus* ATCC 25923 was stated in Table 1. The strongest biostatic activity was observed in case of white and black tea. The reduction of the number of staphylococci was higher than 6 log cfu/cm^2^, Low biostatic activity was recorded for green tea, which could result from the temperature of water used to prepare the infusions in Table 1.

Researches carried out by some investigators revealed lack of synergistic effect of biostatic substances included in the mixture of teas and *Kalanchoe* and citric acid on staphylococci [58]. Yet published literature data does not take into account the research on biostatic efficiency of multi-compound plant blends. Yet carried out researches on biostatics in binary models do not apply to blends of dried leaves and citrus fruit infusions [56].

As far as synergistic activity of *Kalanchoe* tea mixture in relation to staphylococci was observed, as synergistic activity of plant mixture with citrus fruit additive against the population of *Staphylococcus aureus* was not observed. Recorded level of reduction of the mixture containing citric acid from the fruit was by about 2 log cfu/ lower than for infusions without the lemon additive [57].

Population of staphylococci before using *Kalanchoe* was at the level of 6, 27 log cfu. After 1 day of controlled storage insignificant increase of streptococci and staphylococci abundance was reported. After 1 day of storage, the level of staphylococci was similar to the initial value in control samples, and the reduction of micro-organism number of the products after two days at the average from 3,96 log cfu/g up to 2,70 log cfu/g was observed.

Technologies of preservation of plant tissues can have a significant impact on biostatic activity of substances they contain [71]. An example can be the difference in dynamics of staphylococci inhibition by aloe tissue being subjected to different preservation treatments. The results of the studies showed that the addition of fresh aloe pulp to *Staphylococcus aureus* cultures affected the reduction of *S. aureus* abundance. Storing of preserved with high pressure aloe pulp for 1 day in cool conditions, did not significantly influenced the reduction of its biostatic activity.

In this case activity did not depend on the way of tissue preparation - obtained effects were similar for pulp with skin and without skin. However, slightly higher (about 0,3 log cfu) biostatic effect revealed homogenate with skin. The highest biostatic activity revealed aloe pulp with skin and without skin when applied pressure was at a level of 400...
MPa. The application of such preserving technology for 20 minutes allowed the reduction in the number of *Staphylococcus aureus* by up to 0, 79 log cfu/g [49].

A significant reduction of biostatic activity revealed aloe pulp with skin preserved with pressure of 500 MPa. After 20 minutes of such preservation, not decrease but increase of staphylococci by 1,3 log cfu/g was stated. Heck et al (1981) studied aloe extract produced for industrial purposes, and not preserved aloe extract similar to the extract obtained from aloe growing in households [72].

The studies revealed that 40% concentration of preserved aloe extract, its concentration had effective inhibitory activity in relation to selected micro-organisms such as *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*. 10% additive of aloe pulp before pasteurization caused reduction of population of coagulase-positive *Staphylococcus aureus* from 1,5 log cfu/g to 1,7 log cfu/g. These studies proved that aloe pulp pasteurization does not act in favour of aloe pulp maintaining its biostatic properties [49, 73].

High biostatic activity of aloe with skin and without skin macerate was observed when UV tissue preservation method was applied. However, the durability of tissue itself was not satisfying after storage and was not acceptable for use as food additive or as diet supplement.

In practice, there is possibility to use biostatic properties of certain plant tissues of antioxidant and antibacteriological character for food production. Until now yoghurts with lychee, amaranth, guava, aloe or lime were produced. Bacteriostatic properties of these plants could be taken into account in researches and used to prolong the sustainability of food.

Steinka and Kukulowicz studies results reveal that aloe aerosol used in the process of hermetic packing of lactic acid cheese may be relevant for its quality optimization [55].

Micro-flora inhibition on the surface of the product occurs in contact with aloe drops sprayed on the surface of lactic acid cheese before closing the plastic packages.

Plant aerosol can be successfully used to optimize the quality of the plant sprouts. The aerosol obtained from kalanchoe pulp macerated was spray-coated to the surface of plant product directly before hermetic packing of the product into polystyrene box [57].

Using of this system allowed us to obtain the best quality of plant products packaging with rigid polystyrene box. *Klanchoe* was added as 1% and 2% spray on the surface of the sprouts and then the box with supplement products was closed. Results indicate that up to 84,2% of changeability of staphylococci population was dependent on storage time of the sprouts with the kalanchoe spray. During storage of the sprouts with kalanchoe spray the maximum differences in relation to all sprouts were adequately as follows: after 2 days 0,78 log cfu/g for enterococci, 0,96 log cfu/g for staphylococci and 2,91 for *Escherichia coli*. After 2 days of storage, the highest decrease of enterococci amount by 0,78 log cfu/g was observed for broccoli and radish [74].

Synergistic effect of phytoncides and lactic acid fermentation bacteria were used to stabilize the food security. Researches revealed that the level of technological *Lactococcus sp*. micro-flora during the time of lactic acid cheese formation depends on the dose and preparation method of aloe.

Addition of 100 g of aloe pulp caused greater decrease in the number of streptococci and staphylococci to the 4th day of storage of lactic acid cheese curd. Obtained data also revealed an important relation between the influence of storage time and the growth of bacteria population under the influence of aloe [12,45]. Existing samples of using aloe in yoghurt production showed that in this case, the dose of plants in yoghurts must not exceed 35 g of aloe in 100 g of product. Staphylococci inhibition effect in yoghurts with aloe was not observed on the 21th day of storage in comparison to the majority of tested products [75].

Considering the ability to spreading of *Staphylococcus aureus* (LA-MRSA) resistant to antibiotics which is due to foods of animal origin seeking new methods to inhibit staphylococci growth has become the prime matter. Probably, researches on biostatic activity of phytoncides present in plants is one of the factors in the fight against the increasing threat from these bacteria.
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