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Tuning of food wastes bioavailability as feedstock for bio-conversion processes by acoustic cavitation and SPC, SPS, or H_2O_2 as external oxidants

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ABSTRACT

The growing amount of food wastes makes them a suitable source for the generation of bioproducts through anaerobic digestion. Appropriate hydrolysis of the feedstock can enhance the efficiency of production of desired products. In this work, acoustic cavitation (AC) was employed as a pretreatment method to enhance hydrolysis stage by the modification of model (potato-based) food waste for increase in soluble chemical oxygen demand (CODs) and dissolved carbohydrate. For the first time high and low frequency AC was compared for this purpose. The application of sole AC at a frequency of 20 kHz for feedstock loading of 3 % has led to 125 % and 124 % increase in CODs and dissolved carbohydrates, respectively. The combination of AC with external oxidants hydrogen peroxide (H_2O_2), sodium persulfate (SPS), and sodium percarbonate (SPC) was also studied. This part of the studies revealed that SPS has superior properties for increasing CODs by 258 % and dissolved carbohydrates by 240 %. On the other hand, addition of sodium hydroxide (NaOH) as alternative reagent, leads to a 173 % increase in CODs and 155 % increase in dissolved carbohydrates. Making both ways of processing highly effective to increase the bioavailability of food wastes for further biologic processing.

1. Introduction

A large increase in food wastes, as a result of the population growth and economy development, has been one of the universal concern for many years. According to the reports, more than one third of universal consumption of food is thrown out as food waste [1,2]. Proteins, lipids, polysaccharides, fats, and carbohydrates which exist in most types of food waste can be used in some processes for the formation of value-added products such as volatile fatty acids, lactic acids, carboxylic acids, and green fuels such as biogas, biohydrogen, and biodiesel [1,3]. The production of this kind of green energy can be regarded as fulfilling the circular economy approach as well as environmental protection solution due to the utilization of waste and a decrease in acid rains and toxic gas emissions regarding as major universal issues [4].

In anaerobic digestion, the hydrolysis of feedstock is an important stage affecting the whole process. Hence, an inappropriate hydrolysis stage can cause a decrease in the formation of final products [1,5,6]. CODs refers to the soluble organic substances, and an appropriate hydrolysis stage results in a remarkable increase in this factor. The pretreatment of feedstock can lead to an enhancement in the hydrolysis stage through chemical or physical effects, providing an easy access (bioavailability) of feedstock to microbes. Consequently, it can result in the intensification of growth of microbes and production of the desired product [4]. Pretreatment techniques are applied to decrease the size of particles and increase surface area, and as a result, intensify the main anaerobic digestion bioprocesses [7–10]. Pretreatment technologies can also intensify the reactions through increasing mass transfer among different reactants leading to a decrease in the processing time [11]. A one of promising technologies in this field is cavitation.

Cavitation phenomenon is the formation, expansion, and implosion of microbubbles in a short period of time [12,13]. The fast deviations in vapor-liquid interface results in the development of high-speed

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microjets and high corresponding water-hammer pressure [14]. The collapse of bubbles as well as the great influence of microjets on the opposite side of bubble wall lead to the formation of a set of high-speed shock waves [15,16]. Furthermore, the compression of gas and vapor within the bubbles generate tremendously high pressure and temperature [17]. The high temperature and pressure can decompose water molecules and generate $HO^{\bullet}$, $HOO^{\bullet}$, and H_2O_2, possessing high oxidation potential [18]. Moreover, these extreme conditions can result in the cleavage of chemical bonds causing changes in the molecular structure resulting in formation of smaller molecules [19–21]. In general, cavitation is effective in three main areas. Within the bubble, the very high temperature and pressure can supply the activation energy which is needed for decomposition (thermolysis) of gasified solvents and solutes. The produced radicals and products can pass through the walls of bubbles (i.e. gas/liquid interface) and participate in the chemical reactions in the bulk of the solution. Furthermore, in the gas-liquid interface, both cleavage and radical reactions can take place [22].

In AC, this phenomenon takes place through the compression and expansion cycles of acoustic waves formed through the transmission of wave into the medium, which induces negative and positive pressures, leading to the expansion and compression of microbubbles, respectively [23,24]. The suitable design of acoustic reactors and optimum operating conditions are significant factors in the intensification of specific process [25].

Advanced oxidation processes (AOPs) are regarded as efficient techniques which are based on the generation of reactive species attacking molecules and degrade them to produce smaller ones having lower molecular weights [26,27]. Oxidative disintegration is an effective way for the destruction of cell wall structure leading to an increase in the production of desired products in anaerobic digestion [28]. H_2O_2 is a well-known oxidant which can be activated through a variety of methods to produce reactive hydroxyl radicals ($HO^{\bullet}$) [29]. SPS is another oxidant which has a high chemical stability, and therefore, can be transported safely [30,31]. SPS can be activated by various methods including artificial light [32], heat [33], catalyst [34], and cavitation [35] to generate reactive sulfate radicals ($SO_4^{\bullet-}$). SPC is known as solid carrier of H_2O_2, and its transfer and storage is safer than H_2O_2 because of its solid status [36,37]. SPC can be activated to produce reactive species such as $HO^{\bullet}$ and carbonate radicals ($CO_3^{\bullet-}$) [38]. In the case of oxidative pretreatment modifying the feed stock utilized for the production of bioproducts, these oxidants have been activated by UV [38], alkali [39, 40], micro wave [41], and heat [30]. Although, cavitation combined with additional oxidants or catalysts has been widely studied for the aim of wastewater treatment [42,43], up to date, the research on the utilization of these hybrid processes for the pretreatment of feedstocks for anaerobic digestion is scarce. In this study, a comparison was made between low frequency ultrasound reactor and high frequency one, which was rarely studied in the literature, to select the most effective reactor for the rest of experiments. The effects of power density and waste loading were investigated in relation to COD and dissolved carbohydrate values at a low frequency reactor. In addition, the impact of probe diameter to vessel diameter ratio (D_P/D_V) on the performance of acoustic cavitation was studied, which has been scarcely investigated in the case of pretreatment of food waste in the literature. Finally, the outcomes obtained through the addition of H_2O_2, SPS, SPC as well as acid and base were investigated.

2. Material and method

2.1. Materials

Boiled potato was used as simulated food waste. First the potatoes with skin were boiled 20 min in water. After cooling, the boiled potatoes were next skinned, mashed, and then homogenized using a blender (model MQ3, Brown). The prepared slurry was stored at 2 °C for further utilization. Potassium dichromate and silver sulfate were purchased from Pol-Aura (Poland) for the preparation reagent used for the determination of CODs. Sodium hydroxide (99 %), Sulfuric acid (95 %), hydrogen peroxide (30 %), and phenol were provided by POCH (Poland). Sodium persulfate and sodium percarbonate were purchased from Merck (Germany). Glucose was purchased from Warchem (Poland). Sodium hydrogen phthalate was provided by Chempure.

2.2. Experimental set-up

The pretreatment was performed using two different types of reactors. Most of the experiments were done in a reactor with vertical horn with a length of 5 cm working at a frequency of 20 kHz (Hielscher 400th). Another reactor was a self-designed reactor in which the transducers were mounted on the walls of reactor [44]. This reactor was applied in order to study the effect of higher frequency (200 kHz). In both reactors cooling water was utilized to maintain the temperature at 25±3 °C.

2.3. Analysis

The CODs of samples was measured after centrifugation at a speed of 1000 rpm for 25 min, filtration through a membrane filter (0.45 µm, hydrophilic CA, Alchem (Poland)), and dilution by deionized water (obtained from Direct-Q® Water Purification System-Merck Millipore). A 1.00 mL of diluted samples were added into the vials containing 2.5 mL of the COD reagent. A blank sample was also prepared, where 1.00 mL sample was replaced with deionized water. After digestion at 150 °C for 2 h at HACH COD reactor, the absorbance was measured at a wavelength of 620 nm using a HACH DR/2010 spectrophotometer. The calibration curve was determined using sodium hydrogen phthalate dissolved in distilled water. The determination of dissolved carbohydrate was performed according to the colorimetric method introduced by Dubois et al. [45] at a wavelength of 490 nm employing glucose as standard. Standard addition method was employed to minimize the effect of matrix interfering in the analysis of carbohydrate.

3. Result and discussion

In AC, cavitation phenomenon happens through the compression and expansion cycles of acoustic waves formed through the transmission of wave into the medium, which induces negative and positive pressures, leading to the expansion and compression of microbubbles, respectively [23]. The illustration of generation and collapse of bubbles as well as the schematics of acoustic horn reactors and acoustic bath reactors employed in this study are observed in Fig 1.

The pretreatment of food waste using cavitation can be performed by the combination of mechanical and chemical effects resulted from the collapse of bubbles [46]. The mechanical effects include shock waves and shear stress, and the chemical effect include the generation of hydroxyl radicals as a result of hot spot according to Eq. (1) [47,48].

$$H_2O + AC \rightarrow {}^{\bullet}OH + {}^{\bullet}H \quad (1)$$

These effects can cause the depolymerization of large molecules such as starch which is available in the potato and the formation of smaller ones such as glucose, illustrated in Fig. 2.

Various factors influencing the effectiveness of pretreatment through AC were investigated and the outcomes were discussed at the following paragraphs.

3.1. Frequency

Firstly, the pretreatment of food waste was performed using two different reactors with a high frequency of 200 kHz and 20 kHz at two power densities of 230 W L^{-1} and 330 W L^{-1}, pH of 11, and loading of 3 % in 15 min. As it is observed in Fig 3, the results achieved by the reactor

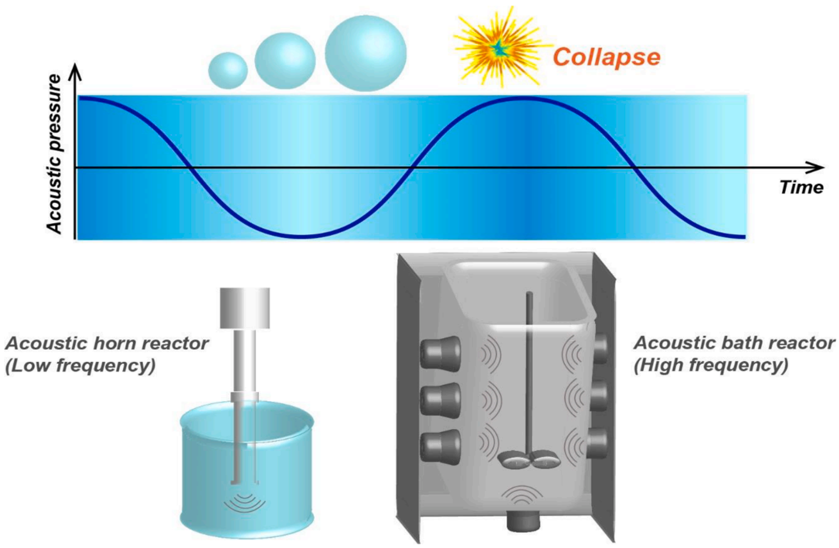

Fig. 1. Schematic of acoustic horn reactor and acoustic bath reactor.

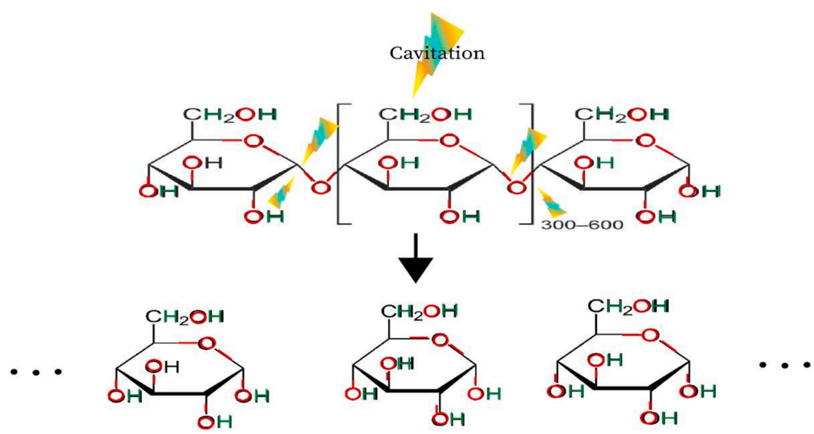

Fig. 2. Depolymerization of starch through cavitation.

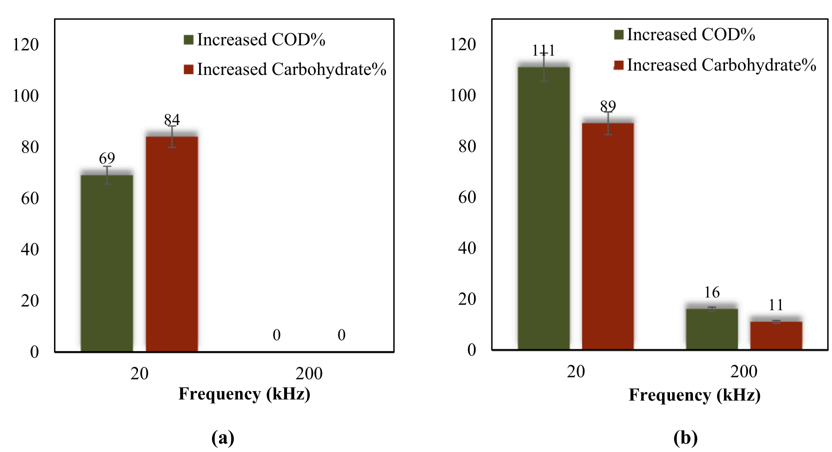

Fig. 3. Effect of frequency on increased CODs and dissolved carbohydrate, a) Power density: 230 W L^{-1}, b) Power density: 330 W L^{-1}.

worked at a high frequency of 200 kHz were drastically lower than the results obtained through cavitation generated in a reactor operated at a low frequency of 20 kHz. At a power density of 230 W L^{-1} and a frequency of 200 kHz, no enhancement was observed in both CODs and carbohydrate in 15 min. At a power density of 330 W L^{-1} and a frequency of 200 kHz, 16 % and 11 % increase were observed in CODs and dissolved carbohydrate, respectively. While at the same power density, 111 % and 89 % enhancement in CODs and dissolved carbohydrate were obtained through a low frequency of 20 kHz.

The difference between the enhancements achieved through these two frequencies can be attributed to the magnitude of physical and chemical aspects of cavitation in different frequencies. An increase in the frequency can lead to a decrease in the size of bubbles and the energy produced through the collapse of bubbles [11,49]. Low frequencies can result in harsher collapse of bubbles and consequently, intensify the physical aspects of cavitation generating stronger shock waves and shear stress, which can break the complex carbohydrate and generate simple ones leading to an enhancement in solubility [18]. A Frequency above 100 kHz causes a decrease in the size of bubbles but it leads an increase in their number, intensifying the chemical aspect of cavitation by increasing the number of produced reactive radicals [50]. Therefore, according to the results, it can be reasonable that the physical aspect of cavitation plays the most important role in the disintegration of food waste.

Since the enhancement achieved by a frequency of 200 kHz in 15 min was very small, the experiments were prolonged to see the results more obvious and the results were demonstrated in Fig. 4. At a power density of 230 W L^{-1}, no enhancement was observed till 45 min and just 11 % and 8 % increase were achieved in CODs and dissolved carbohydrate in 60 min. At a power density of 330 W L^{-1}, a continuous increase was observed in CODs and a maximum enhancement of 32 % was achieved in 60 min. Moreover, dissolved carbohydrate increased till 45 min and then remained constant. A maximum increase of 37 % was observed in dissolved carbohydrate.

As it is obvious, the results achieved at a high frequency of 200 kHz even in 60 min are drastically lower than the results obtained at a low frequency of 20 kHz in 15 min, therefore, the rest of the experiments were performed at the reactor operated at a low frequency of 20 kHz.

It should be mentioned that the difference in the geometry of high frequency reactor and low frequency one can also affect the achieved results.

3.2. Effect of probe diameter to vessel diameter

The ratio of probe diameter to vessel diameter (D_P/D_V) is an important parameter especially when the mechanical aspect of cavitation is valued [51]. Up to date, no investigation has been performed determining the effect of this parameter on the pretreatment of food waste. At the same diameter of vessel, two probes with different diameters providing two values of this ratio were investigated as the mechanical effect of cavitation can decrease the size of particles and have the main responsibility for increasing the solubility of content of food waste. This parameter also has an important influence on the flow behavior of the reactor [51]. Two ratios of 0.2 and 0.3 were investigated at a power density of 330 W L^{-1}, initial pH of 5, and food waste loading of 3 % in 15 min. The outcomes of this investigation are presented in Fig. 5.

An increase in this ratio from 0.2 to 0.3 has led to an enhancement in increased CODs and increased carbohydrate form 28 % to 104 % and from 17 % to 85 %, respectively. This ascending trend follows the fact that higher ratio of D_P/D_V can lead to an increase in overall shear stress and better energy dissipation rate [51]. The high shear stress can result in the breakage of starch structure which is available in the potato leading to the release of carbohydrate into the solution and improving the solubility of organic materials [52]. Furthermore, an increase in this ratio can also result in an increase in turbulence level. The higher ratio of D_P/D_V leads to the more uniform fluid mixing which is required for effective cavitational reactions. However, it should be considered that too large D_P/D_V can cause a decrease in the mixing [51]. These results are particularly important for scaling up of the system. It seems that smaller volume AC flow chamber with proper D_p/D_v will provide better results than immersion of sonotrode (with somehow limited size) in large tank.

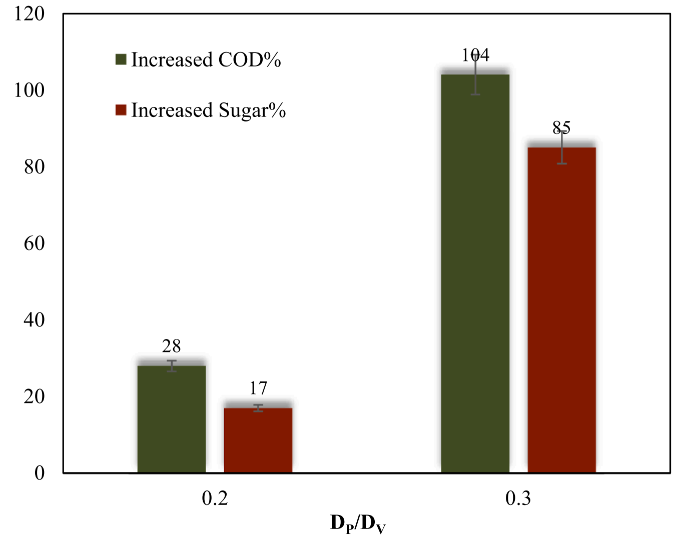

Fig. 5. Effect of D_P/D_V on increased CODs and dissolved carbohydrate (Frequency: 20 kHz, power density: 330 W L^{-1}, initial pH: 5, food waste loading: 3 %, process time: 15 min).

3.3. Effect of power density

Power density is another factor which extremely influences the effectiveness of cavitation. Based on the range of optimum power density for the disintegration of food waste reported in the literature, four different AC power densities in a range of 130–430 W L^{-1} were selected to investigate the effect of power density on the magnitude of CODs and

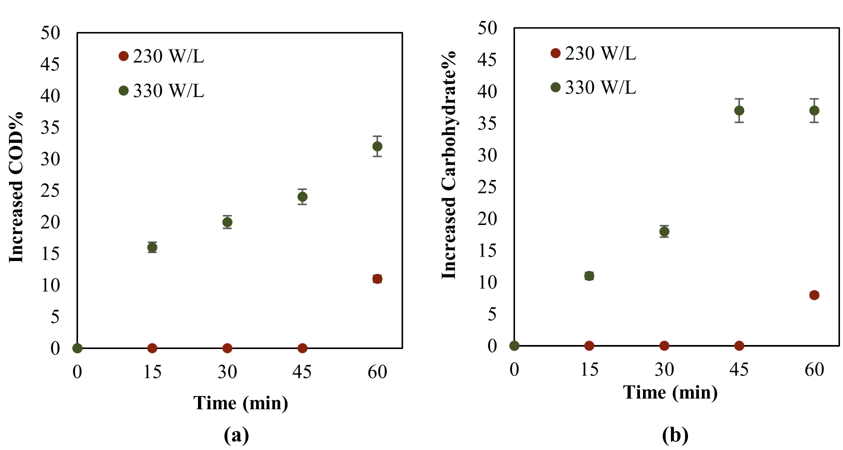

Fig. 4. Increased CODs and dissolved carbohydrate in high frequency of 200 kHz a) Increased CODs, b) Increased carbohydrate.

dissolved carbohydrate. The results were compared in Fig. 6.

As it is shown, an increase in power density has resulted in a continuous increase in CODs and dissolved carbohydrate. The application of AC at power densities of 130 W L^{-1}, 230 W L^{-1}, 330 W L^{-1}, and 430 W L^{-1} has led an increase in CODs by 54 %, 65 %, 104 % and 125 %, respectively. Moreover, along with AC power densities increased also dissolved carbohydrate content increased gradually. The ascending trend is attributed to the fact that low power density is inadequate to break chemical bonds and increase the solubility of processed matter. An increase in power density results in an enhancement in the activity of cavitation [53,54]. However, it is recommended to determine the optimum value of this factor as too high power density can cause the formation of cavity cloud and as a result a reduction in cavitational activity [55]. In current study such effect was not observed.

3.4. Effect of food waste loading

Food waste loading was also investigated as it influences the density of slurry and as a result the cavitational effect. In the case of food waste, substrate loading of feedstock is normally selected below 10% w/v [56]. Therefore, 3 food waste loading values of 1 %, 3 %, and 5 % were studied and the results are demonstrated in Fig. 7.

As it is observed, an increase in loading has continuously led to a decrease (related% values) in dissolved carbohydrate and CODs. This trend can be attributed to this fact that increasing the density of slurry can cause a negative influence on cavitation, which can result in a reduction in value of solubility of organic matters and consequently, CODs [56]. Although food waste particles have this potential to act as nuclei intensifying the intensity of cavitation [34], an extreme increase in substrate loading causes a reduction in water content which leads to a decrease in the strength of cavitation due to a reduction in the generation of bubbles [4]. Since 1 % loading of substrate is inadequate in anaerobic digestion, the rest of experiments were performed at a loading 3 %.

3.5. External additives

After optimization of cavitation conditions, further experiments were performed to evaluate different attempts on enhancement of effectiveness. Two alternative approaches based on external additives were compared: 1) addition of oxidants 2) addition of acid or base to increase the hydrolysis rate.

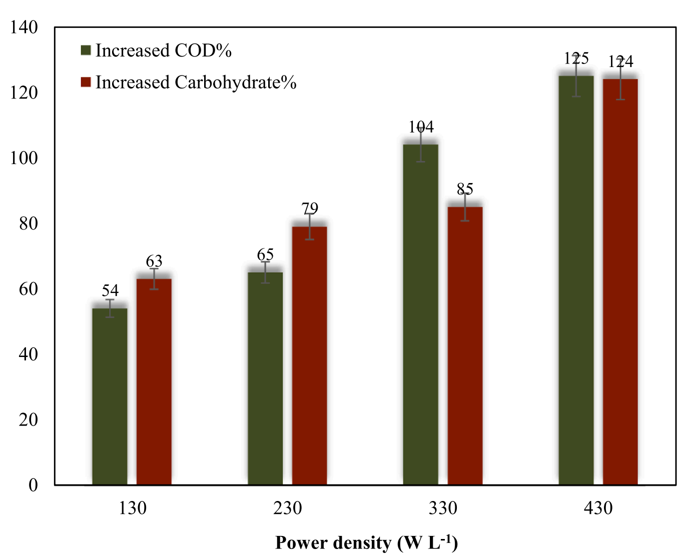

Fig. 6. Effect of power density on increased CODs and dissolved carbohydrate (Frequency: 20 kHz, initial pH: 5, food waste loading: 3 %, D_P/D_V: 0.3, process time: 15 min).

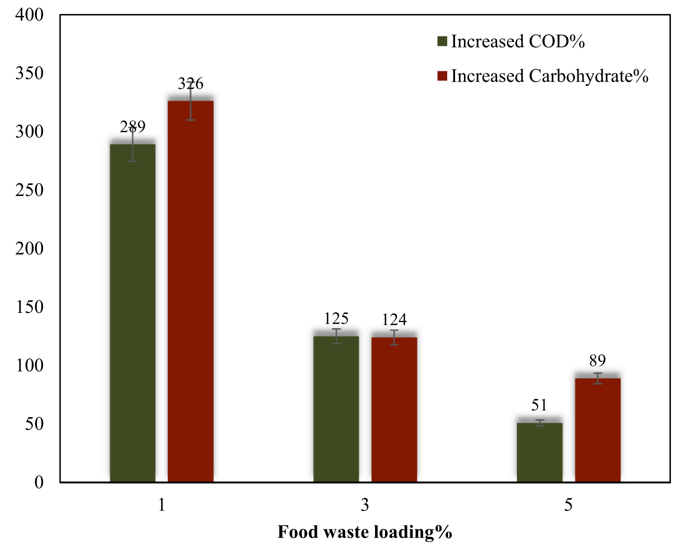

Fig. 7. Effect of food waste loading on increased CODs and dissolved carbohydrate (Frequency: 20 kHz, power density: 430 W L^{-1}, initial pH: 5, D_P/D_V: 0.3, process time: 15 min).

3.5.1. Addition of oxidant

Advanced oxidation processes (AOPs) are regarded as an efficient method which is based on the generation of reactive species [57]. These reactive species have this potential to break down complex molecule structure and generate simpler ones [26,58]. According to the literature, the application of a variety of advanced oxidation processes including ozonation [59], Fenton [27], and peroxone [60] has shown an increase in CODs and improved the properties of waste utilized as substrate in anaerobic digestion to produce biogas. In this study, the combination of low frequency cavitation and oxidants including H_2O_2, SPS, and SPC were investigated at a frequency of 20 kHz, power density of 430 W L^{-1}, food waste loading of 3 %, and a pH of 5. The results were compared to the sole processes to determine the effect of these combined processes on the magnitude of increased CODs and carbohydrate. In order to determine the effect of sole oxidants, the food waste containing the oxidant was mixed on a stirrer at a speed of 1000 rpm in 15 min. The results of this investigation are observed in Fig. 8.

H_2O_2 is a well-known oxidant which can be utilized for the degradation of a variety of pollutants [13]. The combination of H_2O_2 and cavitation can result in the decomposition of H_2O_2 and the generation of reactive hydroxyl radicals ($^{\bullet}OH$) through Eq. (2).

$$H_2O_2 + AC \rightarrow 2^{\bullet}OH \quad (2)$$

This hybrid process has resulted in an increase in CODs and carbohydrates by 158 % and 196 %, respectively. While at the same operating condition, the application of sole AC led to an increase in CODs and carbohydrate by 125 % and 124 %, respectively. Sole H_2O_2 increased CODs and carbohydrate just by 16 % and 17 %, respectively. The higher increase in CODs and carbohydrate caused by the hybrid process compared to the sole processes can be attributed to the fact that generated $^{\bullet}OH$ has this potential to lead to the oxidative disintegration of organic matters. These reactive species can attack the side chains leading to depolymerization of complex molecules and as a result, the generation of simpler ones, which can lead to an increase in the concentration of soluble content including dissolved carbohydrate [28].

The combination of SPS and AC can generate reactive sulfate radicals ($SO_4^{\bullet-}$), possessing a high oxidation potential of 2.6 V, through the symmetrical breakage of peroxide bond according to the Eq. (3) [30].

$$S_2O_8 + AC \rightarrow 2SO_4^{\bullet} \quad (3)$$

This combined process of SPS and AC has led to an increase in CODs

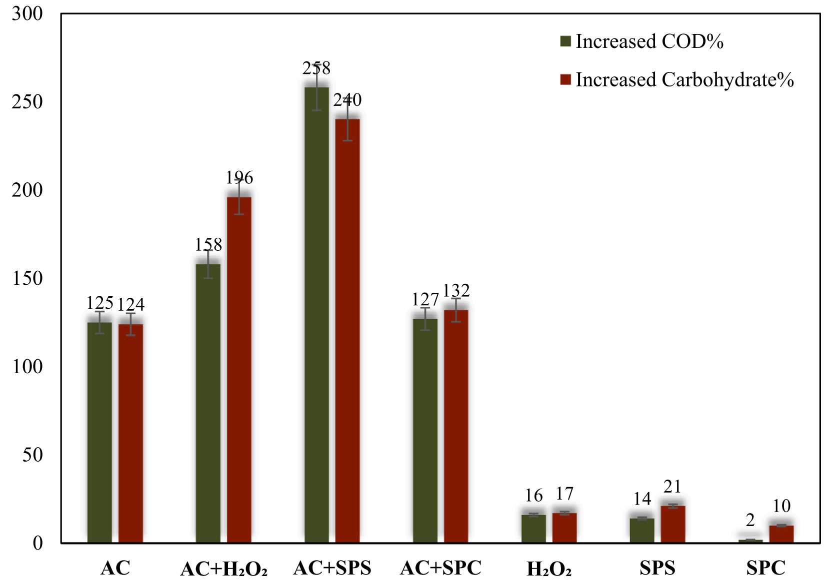

Fig. 8. Comparison between the effect of sole cavitation and the combination of cavitation with H_2O_2, SPS, and SPC on increased CODs and dissolved carbohydrate (Frequency: 20 kHz, power density: 430 W L^{-1}, food waste loading: 3 %, D_P/D_V: 0.3, oxidant concentration: 200 ppm, pH: 5, process time: 15 min).

and carbohydrate by 258 % and 240 %, respectively. Sole SPS increased CODs and carbohydrate just by 14 % and 21 %, respectively. Higher enhancement in CODs and carbohydrate achieved by the addition of SPS compared to H_2O_2 can be related to the fact that $SO_4^{\bullet-}$ generated at the presence of SPS has more stability and longer half-life than hydroxyl radicals produced in the presence of H_2O_2 [61].

These reactive radicals can result in the opening of the rings and cleavage of bonds in the structure, leading to a reduction in the complexity of long-chain molecules and formation of molecules with lower molecular weight which are more suitable for digestion [30,62].

SPC can be used as a solid form of H_2O_2 as it can produce $^\bullet OH$ through following Eqs.

$$2Na_2CO_3{\bullet}3H_2O_2 \rightarrow 2Na_2CO_3 + 3H_2O_2 \quad (4)$$

$$H_2O_2 + AC \rightarrow 2^\bullet OH \quad (5)$$

This hybrid process has resulted in an increase in CODs and carbohydrates by 127 % and 132 %, respectively. Sole SPC increased CODs and carbohydrate just by 2 % and 10 %, respectively. The results achieved by this hybrid process is just a bit higher than the results obtained by sole cavitation, which can be related to the low release of H_2O_2 as well as consumption of $^\bullet OH$ generated by the hydrolysis of water molecules under cavitation through Eq.1 and generation of carbonate radical ($CO_3^{\bullet-}$) which has lower oxidation potential than $^\bullet OH$ according to Eq. (6).

$$CO_3^{2-} + {}^\bullet OH \rightarrow CO_3^{\bullet-} + OH^- \quad (6)$$

Therefore, the optimum amount of these oxidants should be considered for obtaining the maximum improvement in the feedstock in the future research.

It is clear that increase of dissolved COD and carbohydrates can be obtained by addition of small amount (200 ppm level) of the studied oxidants. Application of SPS or SPC demands preparation of solution or mixing of salts, food waste and water during placing into the reactor. In case of H_2O_2 it will be operated as liquid, simplifying the operation. On the other hand, in relation to safety reasons SPS and SPC are better selection. Independently to above aspects, costs of this chemicals must be also taken into account.

3.5.2. Addition of acid or base

The addition of sulfuric acid or sodium hydroxide can also have an influence on the processing of food waste by AC as increased amount of hydronium or hydroxyl ion can contribute to accelerated conversion of primary material. Therefore, the effect of these additives on the magnitude of increased CODs and dissolved carbohydrates were illustrated through the changes in pH and the results are demonstrated in Fig 9.

According to the obtained results, it is clear that an increase in pH has continuously increased both CODs and dissolved carbohydrate. The results are in agreement with the outcomes achieved by Grübel et al. [63] who have studied the effect of alkalization combined with hydrodynamic cavitation and reported that the best results were achieved at a pH of 11. This ascending trend can be related to the possible reason that alkaline pH can weaken the structure of food waste and therefore, accelerate the disintegration achieved through cavitation [63]. On the

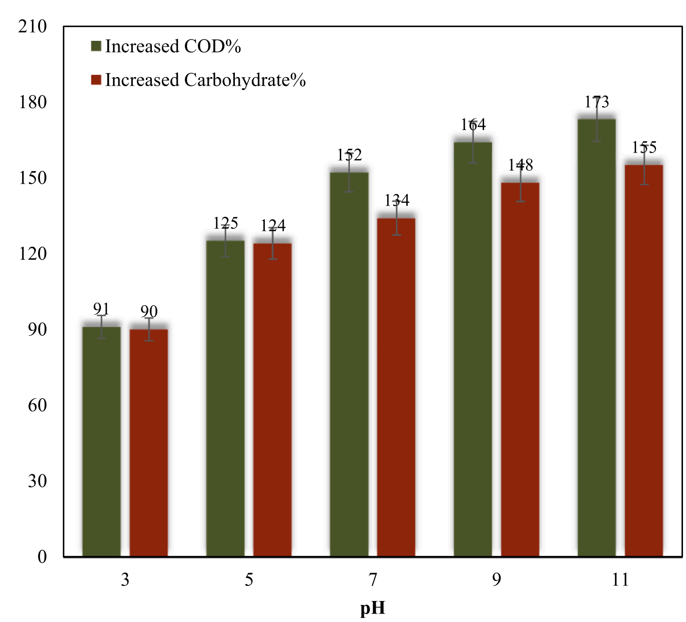

Fig. 9. Effect of pH on increased CODs and dissolved carbohydrate (Frequency: 20 kHz, power density: 430 W L^{-1}, food waste loading: 3 %, D_P/D_V: 0.3, process time: 15 min).

other hand, at elevated pH, presence of excess hydroxyl ions increases the hydrolysis (depolymerization of starch). To confirm the effectiveness of combination of AC and alkaline conditions, the effect of sole alkaline conditions on the properties of food waste was also investigated. Hence, as pH of 11 led to the best results, solution of food waste was prepared at a pH of 11 (adjusted by NaOH) and it was mixed on a stirrer at a speed of 1000 rpm in 15 min without AC. This process resulted in just 6 % and 7 % increase in CODs and dissolved carbohydrate, respectively, while at the same conditions, the combination of NaOH and AC led to 173 % increase in CODs and 153 % increase in dissolved carbohydrate in 15 min, proving the significant advantage of the combined process.

It was proved that an alternative for oxidative reagent to enhance the bioavailability of the feedstock is to apply sodium hydroxide, which is a safe, cheap and widely available chemical. However, in this case post-processed feedstock will demand pH correction prior to biological processing.

4. Conclusions

AC has demonstrated its potential to increase the concentration of soluble substances, which can increase the availability of them to the microorganisms in the anaerobic digestion processes. A low frequency of 20 kHz was remarkably more effective than a high frequency of 200 kHz. At a power density of 230 W L^{-1} and a frequency of 200 kHz, no increase has been achieved in both CODs and carbohydrate, while, at a low frequency of 20 kHz, 69 % and 84 % increase in CODs and carbohydrate have been obtained. At a power density of 330 W L^{-1} and frequencies of 200 kHz and 20 kHz, 16 % and 111 % enhancement in CODs, and 11 % and 89 % increase in dissolved carbohydrate were obtained, respectively. Hence, the rest of experiments were performed at a low frequency of 20 kHz. A higher ratio of probe diameter to vessel diameter (D_P/D_V) of 0.3 has resulted in a noticeable increase in CODs by 104 % and dissolved carbohydrate by 85 % compared to 28 % increase in CODs and 17 % increase in dissolved carbohydrate achieved at a lower D_P/D_V of 0.2. An increase in power density from 130 W L^{-1} to 430 W L^{-1} continuously increased the CODs and dissolved carbohydrate from 54 % and 63 % to 125 % and 124 %, respectively. A decrease in food waste loading has also led to an increase in CODs and dissolved carbohydrate. The combination of cavitation and SPS has resulted in enhancement of CODs and dissolved carbohydrate by 258 % and 240 %, respectively. While, at the same operation condition, sole cavitation and the combination of cavitation with H_2O_2 and SPC have resulted an increase in CODs by 125 %, 158 %, and 127 %, and an increase in dissolved carbohydrate by 124 %, 196 %, and 132 %, respectively. Moreover, an increase in pH up to 11 providing by the addition of NaOH increased CODs by 173 % and dissolved carbohydrate by 155 %.

Future research in this field will include pilot scale studies for as obtained feedstock to analyze routes of bioconversion depending on method of food waste pretreatment, as application of AOPs can change the profile of produced value-added by-products of fermentation (like carboxylic acids, alcohols and furfural derivatives).

CRediT authorship contribution statement

Zahra Askarniya: Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Lingshuai Kong:** Writing – review & editing. **Chongqing Wang:** Writing – review & editing. **Shirish H. Sonawane:** Writing – review & editing. **Jacek Mąkinia:** Writing – review & editing, Funding acquisition, Resources. **Grzegorz Boczkaj:** Conceptualization, Methodology, Validation, Project administration, Supervision, Resources, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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