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Enhanced production of short-chain fatty acid from food waste stimulated by alkyl polyglycosides and its mechanism

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ABSTRACT

Short-chain fatty acids (SCFAs) are the valuable products derived from the anaerobic fermentation of organic solid waste. However, SCFAs yield was limited by the worse solubilization and hydrolysis of particulate organic matter, and rapid consumption of organic acid by methanogens. In this study, an efficient and green strategy, i.e. adding biosurfactant alkyl polyglycosides (APG) into anaerobic fermentation system, was applied to enhance SCFAs production from food waste. Experimental results showed that APG not only greatly improved SCFAs production but also shortened the fermentation time for the maximum SCFAs accumulation. The SCFAs yield at optimal APG dosage 0.2 g/g TS (total solid) reached 37.2 g/L, which was 3.1-fold of that in blank. Meanwhile, the time to accumulate the maximum SCFAs in the presence of APG was shortened from day 14 to day 6. The activities of key enzymes such as hydrolytic and acid-forming enzymes were greatly promoted due to the presence of APG. These results demonstrated that the enhanced mechanism of SCFAs production should be attributed to the acceleration of solubilization and hydrolysis, enhancement of acidification and inhibition of methanogenesis by APG.

1. Introduction

The eutrophication led by the excessive discharge of phosphorus and nitrogen into water body has become a severe pollution problem all around the world. Under most circumstances, available biodegradable carbon, such as short-chain fatty acids (SCFAs) is a critical substrate for higher performance of biological nutrient removal (BNR). Usually, 1.07–1.82 and 1.87–3.00 mg SCFAs is required to remove 1 mg N and 1 mg P, respectively (Elefsiniotis and Li, 2006; Luo et al., 2015). However, available carbon source in wastewater is always insufficient (Tan et al., 2012; Zhao et al., 2015a). Several studies have demonstrated that fermentative SCFAs as the additional carbon source could result in superior BNR performance (Tong and Chen, 2007; Moser-Engeler et al., 1998).

Compared with the expensive synthetic volatile fatty acids (VFAs), SCFAs derived from anaerobic fermentation of organic solid wastes are more cost-effective and environmentally friendly. In general, anaerobic digestion includes three steps, namely solubilization and hydrolysis, acidification and methanogenesis (Chen et al., 2013a; Luo et al., 2015; Zhao et al., 2015b). Among them, solubilization and hydrolysis are considered as the rate-limiting steps (Chen et al., 2013a), and thermal, chemical, enzymatic and mechanical pretreatments have been applied to accelerate the solubilization and hydrolysis of organic solid wastes (Lee et al., 2014; Zhao et al., 2010, 2015b). Recently, it was reported that surfactant could cause positive effects on waste activated sludge (WAS) solubilization and hydrolysis, thereby improving the production of SCFAs (Jiang et al., 2007a; Chen et al., 2013a). Surfactants possess good solubilization ability, so the additional surfactants can enhance the solubilization of extracellular polymeric substances and break the sludge matrix (Jiang et al., 2007a), resulting in more inner carbohydrate and protein release. These, in turn, provide more substrates for hydrolytic bacteria and acid-producing bacteria (Jiang et al., 2007b). However, these investigated surfactants, such as Tween 20, Tween 80, Triton X-100, sodium dodecyl sulfate (SDS) and sodium dodecyl benzene sulfonate (SDBS) are chemosynthetic, which present a potential risk for environment and human health (Kanga et al., 1997). Biosurfactants, with the characteristics of biodegradation and low toxicity, are more desirable in environmental application (Zhang et al., 2009). In our pre-

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vious research, rhamnolipid (RL), a common biosurfactant, enhanced VFAs production from WAS fermentation and the maximum yields of VFAs reached 1829.9 mg COD/L at 0.3 g RL/g dry sludge (DS), which almost tripled versus the blank test (Yi et al., 2013).

Because WAS contains large amount of organic matters such as protein and carbohydrate, they are considered as the favourite substrates to produce the SCFAs (Yuan et al., 2006; Jiang et al., 2007a; Wang et al., 2013; Lee et al., 2014). It is well known that food waste is also the main biodegradable solid waste containing higher levels of organic materials such as carbohydrate and protein than WAS (Chen et al., 2013b). Hence, food waste may be another valuable biomass resource for SCFAs production. In China, the total amount of food waste was 88.8 million tons in 2006 (Zhang et al., 2010), and this value kept on increasing. Anaerobic digestion is preferred as an efficient pathway for the recycling and reduction of food waste. However, food waste was only used as carbohydrate substrate to adjust the C/N ratio during the co-fermentation with WAS (Chen et al., 2013b; Feng et al., 2009). Few studies focus on SCFAs production using food waste as the sole substrate (Feng et al., 2009; Chen et al., 2013b; Wang et al., 2014).

Alkyl polyglycoside (APG) is a mild non-ionic surfactant but it has the properties of both non-ionic and anionic surfactants. Recently, it was successfully applied to improve the degradation of agricultural wastes (Zhang et al., 2011) and WAS (Luo et al., 2015). In this study, an efficient and green strategy, i.e. adding APG into anaerobic fermentation systems, was explored to enhance SCFAs generation from food waste. Firstly, the effect of APG dosage on the SCFAs production was comprehensively evaluated, the composition of SCFAs was also examined. Then the mechanism of enhanced SCFAs production was discussed from the views of APG impact on the different phases of anaerobic digestion.

2. Materials and methods

2.1. Food waste, APG and inocula

Food waste, collected from the canteen in the campus of Hunan University (Changsha, China), mainly consisted of rice, vegetables, meat and bean curd. After removing the animal bones, clamshells and the superficial oil, food waste was smashed into small particles (1–3 mm) by an electrical blender. Then, a certain volume of tap water (food waste: tap water = 10/1, V/V) was supplied into the food waste and fully mixed until the mixture presented fluid state. The food waste had 24.9 ± 0.8% total solid (TS), 19.4 ± 0.4% volatile suspended solid (VSS) and 134.5 ± 6.5 g chemical oxygen demand (COD)/L total carbohydrate, 46.8 ± 2.4 g COD/L total protein.

The biosurfactant APG used in this study was obtained from Nanjing Duly Biotech Co. Ltd. (Jiangsu Province, China). The main characteristics of APG were as follows: solid content 50%, density 1.10 g/cm^3.

WAS, the inoculum of anaerobic fermentation, was obtained from the secondary sedimentation tank of a wastewater treatment plant in Changsha, China. The main characteristics of sludge after settling at 4 °C for 24 h are as follows: total chemical oxygen demand (TCOD) 15.2 ± 0.5 g/L, TS 12.6 ± 0.4 g/L, VSS 9.8 ± 0.4 g/L.

2.2. SCFAs production in the presence of APG

Batch experiments of SCFAs production from food waste in presence of APG were conducted in a series of identical anaerobic reactors, which were made of plexiglass and each had a working volume of 1.0 L. C/N ratio is an important factor affecting the anaerobic fermentation of organic substrates, whose suitable value is 20/1–30/1 (Parkin and Owen, 1986). In this study, WAS served as the inoculum as well as balanced the C/N ratio of the fermentation substrate. Thus, the ratio of food waste and inoculated sludge was kept 9:1 (V/V) to ensure that the C/N ratio was in the range of 20–30/1. APG was added with its dosage to total food waste solid ratio of 0.05, 0.1, 0.2, 0.3 and 0.4 g/g TS, respectively. Another two reactors were set as the blank test and comparison test respectively: blank test was without APG addition and comparison test was filled only WAS. After feeding, all reactors were flushed with nitrogen gas to eliminate oxygen, sealed with rubber stoppers and fermented for 15 days. During experiments, all the reactors were mechanically stirred at 120 rpm (rotations per minute) and operated at 37 ± 0.5 °C without pH control. The samples withdrawn from reactors were used to analyze the concentration of SCFAs and their compositions to explore the effect of APG on the production of SCFAs.

2.3. Mechanisms for improved SCFAs production by APG

2.3.1. Effect of APG on solubilization of food waste

As food waste is rich in polysaccharide and protein, thus the effect of APG on solubilization of food waste could be evaluated by assaying the soluble protein and polysaccharide contents in fermentation liquor from above batch fermentation experiments.

2.3.2. Effect of APG on the hydrolysis of solubilized organic matter

In order to investigate the effect of APG on the hydrolysis of solubilized organic matter, bovine serum albumin (BSA, average molecular weight (Mw) 67,000) and dextran (Mw 23,800) were chosen as the model protein compound and polysaccharide compound to stimulate the solubilized food waste, respectively. According to the mass ratio of protein to carbohydrate in raw food waste, 0.5 g BSA and 1.15 g dextran were dissolved into 900 mL tap water, and 100 mL WAS fed as the inocula. Then APG was added with the concentration of 0.2, 0.4, 0.8, 1.2 and 1.6 g/L, which were the same as those applied in parent reactors. 40 mM of 2-bromoethanesulfonate was also added to inhibit the activities of methanogens (Xu et al., 2010). The anaerobic fermentation conditions maintained the same as mentioned above. Then, the hydrolysis efficiencies of BSA and dextran during fermentation process were determined by measuring the degradation rate. The identical simulation method was also conducted in the literatures (Zhao et al., 2010; Chen et al., 2013b; Yuan et al., 2006; Luo et al., 2015).

2.3.3. Effect of APG on acidification of hydrolyzed products

The experiments of the influence of APG on the acidification of hydrolyzed products were similar to the hydrolysis process except that 0.4 g L-alanine (model amino acid compound) and 1.6 g glucose (model monosaccharide compound) were used to stimulate the hydrolyzed products. The effect of APG on the acidification of hydrolyzed products was determined by detecting model compounds degradation.

2.3.4. Effect of APG on the methanogenesis

The impact of APG on the methanogenesis was investigated in serum bottles as batch model with synthetic wastewater containing sodium acetate (NaAc). The chemical composition of synthetic wastewater is: NaAc (0.5 g/L), potassium phosphate (50 mM, pH 7.0), KCl (0.13 g/L), NH_4Cl (0.31 g/L), trace element solution (0.5 mL/L) and vitamin solution (0.5 mL/L). The detail information of trace element solution and vitamin solution are described in the literatures (Atlas, 1993; Zhou et al., 2013). All other operations were the same as the fermentation experiments described above.

2.4. Analytical methods

Samples from anaerobic reactors were immediately filtered through a Whatman GF/C glass microfiber filter (1.2 mm pore size). The filtrate was used to detect SCFAs, soluble COD (SCOD), carbohydrate and protein, and the filter was assayed for TS and VSS. The analyses of SCOD, TS, VSS and pH were conducted according to the standard methods (APHA, 2005). The measurements of SCFAs, methane, BSA, dextran, L-alanine and glucose were the same as described in previous studies (Yuan et al., 2006; Tong and Chen, 2007). The total SCFAs content was calculated as the sum of measured acetic, propionic, n-butyric, iso-butyric, n-valeric and iso-valeric acids. The individual SCFA was converted to COD using appropriate conversion factor (Eastman and Ferguson, 1981). Protein was determined by the Lowry–Folin method using bovine BSA as the standard (Lowry et al., 1951), carbohydrate was measured by the phenol–sulfuric method using glucose as the standard (Herbert et al., 1971). The COD conversion coefficients are 1.5 g COD/g protein and 1.06 g COD/g carbohydrate (Wang et al., 2015). The analysis of APG was same as the literature (Lan et al., 2000). The activities of key hydrolytic enzymes (protease and α-glucosidase) were determined according to the method proposed by Goel et al. (1998) and the specific activities of acid-forming enzymes including phosphotransacetylase (PTA), phosphotransbutyrylase (PTB), acetate kinase (AK), butyrate kinase (BK) were determined according to the methods described in our previous publications (Wang et al., 2013; Zhao et al., 2015c).

2.5. Statistical analysis

All experiments were performed in triplicate. An analysis of variance was applied to evaluate the significance of results, and $p < 0.05$ was considered to be statistically significant.

3. Results and discussion

3.1. Effect of APG dosage on SCFAs production from food waste

The total SCFAs production at different APG dosage with fermentation time is shown in Fig. 1a. It can be found that SCFAs production was greatly enhanced by APG (Fig. 1a). When APG dosage was 0.05, 0.1, 0.2, 0.3 and 0.4 g/g TS, the SCFAs production achieved the maximum concentration of 21.4, 30.0, 37.2, 39.0 and 40.3 g/L, respectively. Obviously, the bioconversion of substrates into SCFAs was greatly enhanced due to the presence of APG. Meanwhile, the maximum SCFAs concentration was only 12.0 g/L in blank and no remarkable SCFAs accumulation was observed for the comparison. It is worthwhile to note that the yield of SCFAs at 0.2 g APG/g TS was 3.1-fold of that in blank. Although further increase APG dosage from 0.2 g/g TS to 0.4 g/g TS could cause higher SCFAs generation, the SCFAs production increases were insignificant as compared with that from the food waste with 0.2 g/g TS ($p > 0.05$). In addition, the fermentation time for maximal accumulation of SCFAs was greatly shortened from day 14 to day 6 due to the addition of APG. In the view of practical applications, the shortening of fermentation time for the highest SCFAs accumulation could gave lots of benefits, such as the reduction of device. Therefore, the optimal conditions for SCFAs production from food waste stimulated by APG was 0.2 g APG/g TS and fermentation time of day 6.

The composition of SCFAs is critical to downstream applications (Lee et al., 2014). For the nitrogen removal process, denitrifying bacteria have preference for lower molecular weight SCFAs, such as acetate (Elefsiniotis and Wareham, 2007). However, Chen et al. (2004) reported that increasing propionic acid content in the domestic wastewater resulted in higher phosphorus removal. The

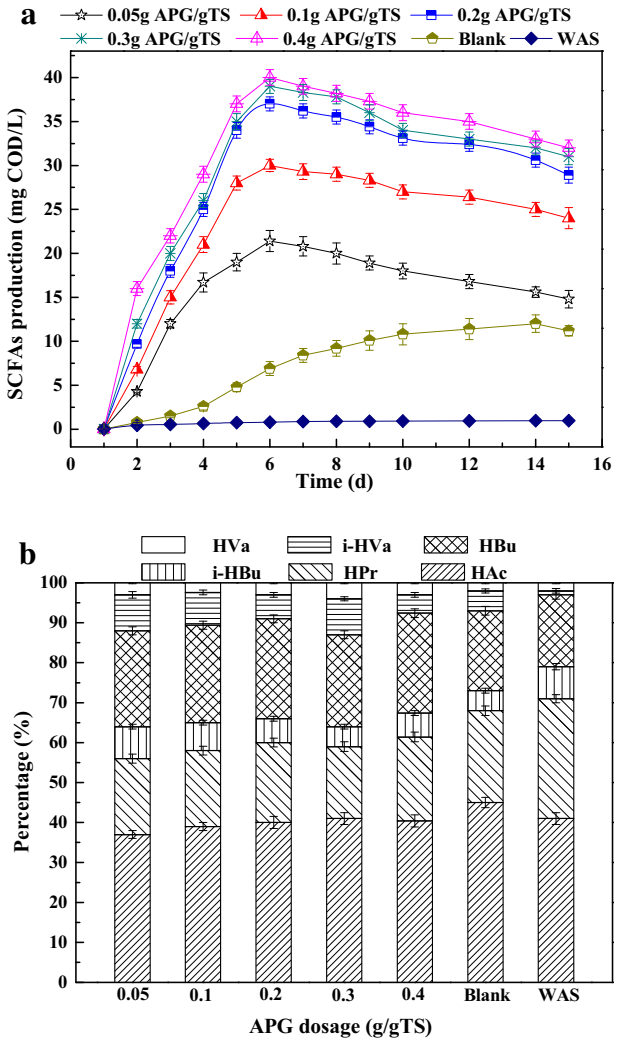

Fig. 1. Effect of APG dosage on the total SCFAs production from food waste fermentation with time (a) and the fraction of individual SCFAs under optimal conditions (b). (HAc: acetic acid; HPr: propionic aid; i-HBu: iso-butyric acid; HBu: n-butyric acid; i-HVa: iso-valeric acid; HVa: n-valeric acid) Error bars represent standard deviations of triplicate determination.

influence of APG on the composition of SCFAs was also investigated. As shown in Fig. 1b, the compositions of SCFAs produced were similar regardless of whether APG was added or not. Acetic acid was the top individual SCFA in all anaerobic reactors, followed by butyric acids. Meanwhile, more percentage of valeric acid was observed in the food waste fermentation liquid. However, the composition was different in the comparison test fed with WAS, where the three top individual SCFAs were as follow: acetic acid (41.0%) > propionic acid (30.0%) > butyric acid (26.3%). The reason for this might be attributed to that food waste used in this study was rich in carbohydrate (from rice and vegetables) and protein (from meat and bean curd) accounted for 52.3% and 18.2% of TCOD, whereas the percentages of carbohydrate and protein were 10.3% and 67.4% in WAS, respectively. It was reported that acetic, propionic and butyric acids can be generated directly from the fermentation of soluble carbohydrates, proteins, and lipids (Horiuchi et al., 2002), while iso/n-valeric acid was mainly generated from proteins degradation (McInerney, 1988). Meanwhile, we found that the proportion of individual SCFAs in food waste fermentation liquids changed little with the change of APG dosage, which demonstrated that the proportion of individual SCFAs was determined mainly by

the substrate source. Previous research showed that the suitable nutrients, expressed as C/N ratio, in fermentation substrates were necessary for acidogenic bacteria to produce SCFAs efficiently (Feng et al., 2009). It has been reported that the suitable C/N ratio for anaerobic digestion should be 20/1–30/1 (Parkin and Owen, 1986), but C/N of WAS is only around 7.1/1. Compared with WAS, food waste is more ideal substrate to produce special composition of SCFAs because its C/N can flexibly adjust by changing the constituent of food waste.

3.2. Effect of APG on solubilization and hydrolysis

The main organic matters in food waste are carbohydrate and protein in the form of particulates which are required to be converted to soluble compounds before subsequent SCFAs production. In general, the solubilization of particulate organic-carbon was expressed in terms of soluble protein and polysaccharide concentrations in fermentation liquor (Tong and Chen, 2007). Fig. 2 describes the effect of APG on the soluble carbohydrate and protein concentrations during the entire fermentation time. With the increase of APG dosage in the range 0.05–0.4 g/g TS, the concentration of soluble carbohydrate and protein in fermentation liquor increased significantly and the fermentation time required for the highest concentration also was shortened from day 12 to day 4. When the APG addition was 0.05, 0.1, 0.2, 0.3 and 0.4 g/g TS, respectively, the highest concentrations of soluble carbohydrate (soluble protein) concentrations were 6.7 (1.21), 8.4 (1.42), 10.2 (1.86), 11.0 (1.93) and 11.8 (1.98) g COD/L at the fermentation time of day 4. Whereas, only 0.8 (0.15) g COD/L soluble carbohydrate (soluble protein) was detected in blank. In the current reactors, almost all the particulate carbohydrate (protein) were derived from food waste, more soluble carbohydrate (protein) indicated that more particulate organic compounds in food waste were transformed into soluble ones in the presence of APG. At the same time, we also noticed that the concentrations of soluble carbohydrate and protein were first greatly increased to the maximum value over fermentation time and then gradually decreased to a low level. These declines suggested that the soluble carbohydrate and protein were consumed for SCFAs production. In addition, the reduction of VSS was also used to evaluate the solubilization of particulate organics during food waste anaerobic fermentation. The VSS reduction with 0.2 g/g TS APG was 12.8% at the fermentation time of day 4, whereas that in blank was only 3.9%. Those observations suggested the solubilization of particulate organics in food waste anaerobic fermentation system was greatly enhanced in the presence of APG.

The impact of APG on the hydrolysis of solubilized food waste was investigated with synthetic wastewater containing model polysaccharide (dextran) and model protein (BSA) and the results were shown in Fig. 3. The hydrolysis efficiencies of dextran and BSA were 63.1% and 25.4% in blank at the time of day 4, whereas, the corresponding data were 95.4% and 67.8% when the dosage

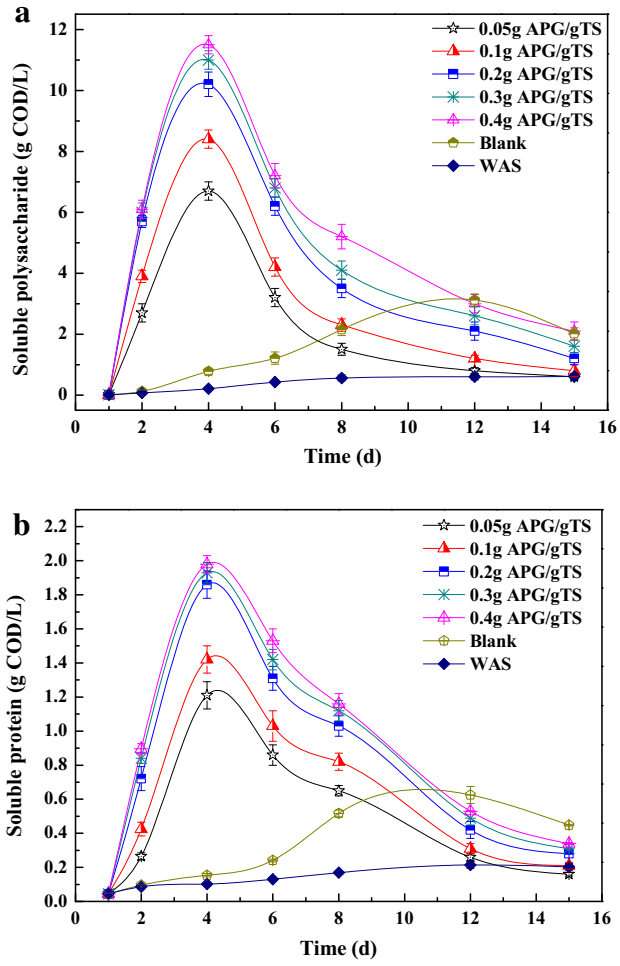

Fig. 2. Variation of soluble polysaccharide (a), protein (b) concentrations with time in the presence of APG. Error bars represent standard deviations of triplicate determination.

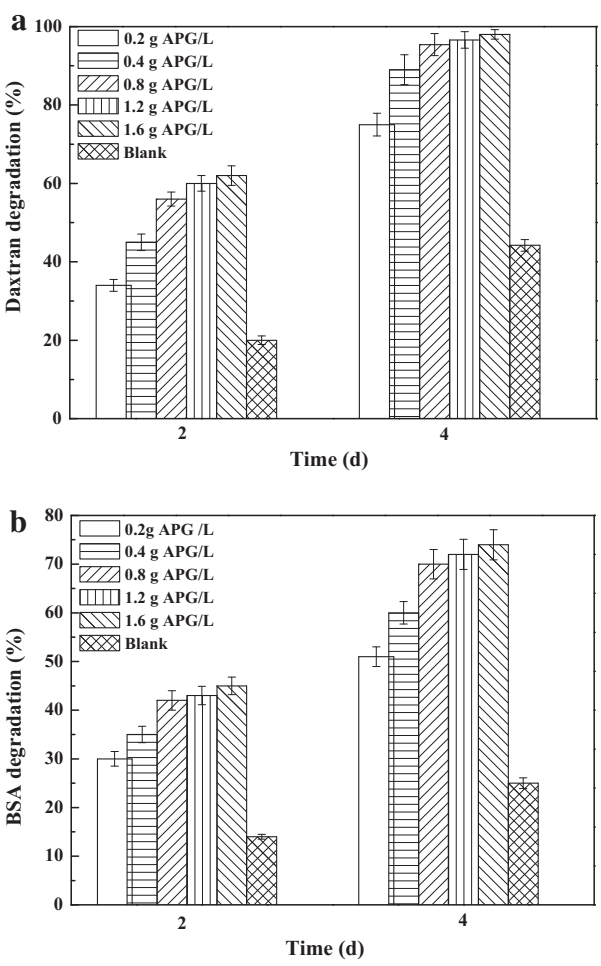

Fig. 3. Effect of APG dosage on hydrolysis of soluble organic matters. Dextran, BSA are model compounds of carbohydrate and protein, respectively. Error bars represent standard deviations of triplicate determination.

of APG was 0.8 g/L, respectively. Furthermore, soluble nitrogen such as NH_4^+-N is always released during protein hydrolysis. In this study, the highest concentration of NH_4^+-N in the blank was only 68.9 mg/L, while it increased to 102.5, 143.2, 175.9, 183.6 and 189.7 mg/L with 0.2, 0.4, 0.8, 1.2 and 1.6 g/L APG addition, respectively. The same phenomena were observed in the improved composting of agricultural wastes by APG (Zhang et al., 2011). These results adequately consolidated the positive function of APG on the hydrolysis of solubilized substrates.

3.3. Effect of APG on acidification

Synthetic wastewater with model compounds (L-alanine and glucose) was used to investigate the influence of APG on the acidification of hydrolyzed products from food waste anaerobic fermentation. As shown in Table 1, the model compounds (glucose and L-alanine) degradation and SCFAs production increased with elevating APG dosage. At the hydrolysis time of day 4, the degradation of glucose and L-alanine with APG 0.8 g/L reached to 94.2% and 82.5%, respectively. Meanwhile, it was only 54.2% and 41.8% in blank. Moreover, when APG dosage was above 0.8 g/L, the benefit of APG to the degradation of model compounds was insignificant ($p > 0.05$). It is suggested that the presence of APG can enhance the acidification of hydrolyzed products, but excessive APG did not result in better acidification.

3.4. Effect of APG on methanogenesis

In this study, we found that the APG had the negative impact on the activities of methanogens through the experiments of synthetic wastewater containing NaAc. As shown in Fig. 4, the cumulative methane production was 48.0%, 34.1%, 24.0%, 21.1% and 19.2% of that in blank at the fermentation time of day 15, with APG dosage of 0.2, 0.4, 0.8, 1.2 and 1.6 g/L, respectively, which suggested that the methanogenesis of acidified compounds was seriously inhibited by APG. Zhou et al. also noticed that the obvious inhibition of methanogens activity in the presence of rhamnolipid, a kind of most known glycolipid biosurfactants and the accumulated methane production decreased sharply from 58.8 mL/g VSS (blank) to 2.0 mL/g VSS (RL 0.04 g/g TS) at the fermentation time of 192 h (Zhou et al., 2013). The serious inhibition on methanogenesis in the presence of APG should be attributed to the drop of pH due to the enhanced accumulation of SCFAs led by APG itself. It is well known that methanogens are sensitive to ambient pH, and the optimum pH was around pH7 (Yuan et al., 2006; Chen et al., 2013a). Fig. 5 showed the variations of pH in food waste anaerobic fermentation reactors. Accompanied by the accumulation of SCFAs, pH drop was observed in all food waste anaerobic treatment reactors. The pH value dropped from the initial 6.8–5.8 on day 6 with 0.2 g APG/g TS, whereas, pH only dropped to 6.5 in blank on day 6. It suggested the presence of APG resulted in more pH drop, which caused stronger inhibition on the methanogens, thereby promoting SCFAs production. Furthermore, the surfactants itself could suppress the activities of methanogens. It was reported that the surfactants inhibited the activities of methanogens in anaerobic system by disrupting their cell membrane (Garcia et al., 2006). Thus, it could be supposed that the co-function of pH drop and APG inhibition make methanogens activities decrease during anaerobic fermentation of food waste. As a result, less SCFAs consumption in methanogenesis led more accumulation of SCFAs in the presence of APG.

Table 1
Degradation of glucose and L-alanine with different APG dosage on day 4.[a]

APG dosage (g/L)	Glucose degradation (%)	L-alanine degradation (%)	SCFAs production (g/L)
0	54.2 ± 1.2	41.8 ± 1.7	1.11
0.2	73.5 ± 1.1	62.1 ± 1.8	1.54
0.4	84.2 ± 1.6	74.6 ± 1.5	1.79
0.8	94.2 ± 2.1	82.5 ± 2.3	2.01
1.2	95.4 ± 2.6	84.6 ± 2.9	2.15
1.6	96.2 ± 2.8	85.6 ± 1.2	2.21

[a] Error bars represent standard deviations of triplicate determination.

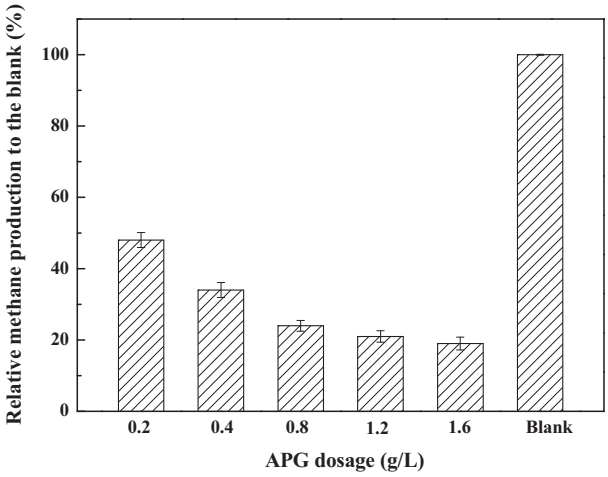

Fig. 4. Comparison of the relative methane production with different APG dosage. Error bars represent standard deviations of triplicate determination.

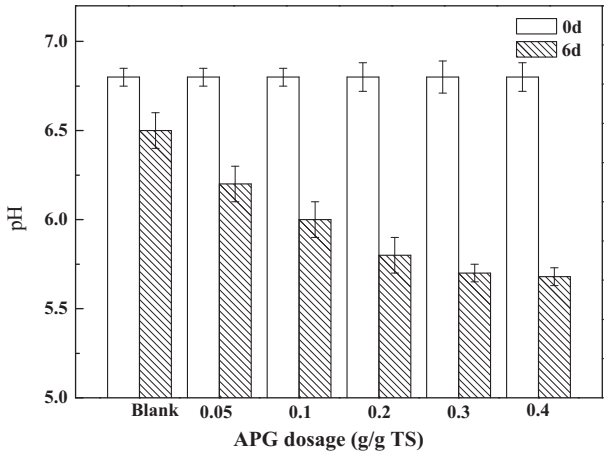

Fig. 5. Changes of pH values with different APG dosage. Error bars represent standard deviations of triplicate determination.

3.5. Activities of key enzymes for SCFAs production in the presence of APG

Lots of enzymes such as hydrolytic enzymes and acid-forming enzymes are involved in the metabolic pathway for the production of SCFAs from organic compounds (Luo et al., 2013). Protease and α-glucosidase are the main key enzymes related with hydrolysis of protein and carbohydrate, respectively (Goel et al., 1998). PTA and AK are the key acid-forming enzymes responsible for the transformation of acetyl-CoA to acetic acid, while PTB and BK are the key acid-forming enzymes that convert butyryl-CoA to butyric acid (Wang et al., 2013). In order to further understand the mechanism for SCFAs accumulation, the activities of these key enzymes on day 6 with 0.2 g APG/g TS were measured. As shown in Fig. 6, the specific activities of those key enzymes were enhanced

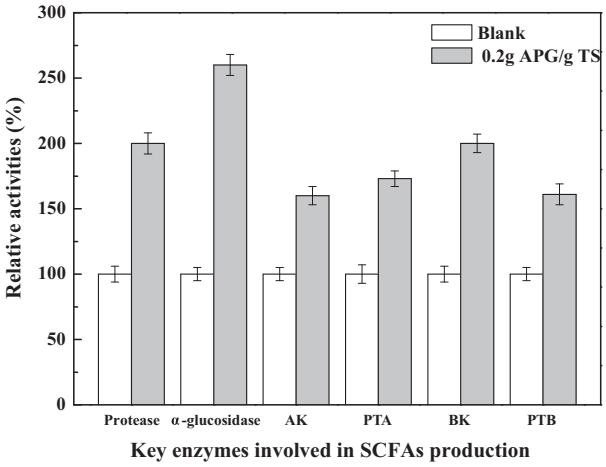

Fig. 6. Effect of APG on the activities of key enzymes involved in SCFAs production. Error bars represent standard deviations of triplicate determination.

remarkably in the presence of APG. he promotion of protease and α-glucosidase activities (enhanced by 100% and 165% with APG) indicated that more food wastes were solubilized into soluble protein and carbohydrate, coinciding with the results shown in Fig. 2. Simultaneously, the activities of PTA and AK closely related with the formation of acetic acid were also increased respectively by 1.7- and 1.6-fold compared with that in the blank, which well explained why the yield of acetic acid in APG treatment system is the highest. Obviously, the improvement of the activities of key enzymes by APG enhanced the production and accumulation of SCFAs.

3.6. Variations of APG during anaerobic fermentation

In order to know whether APG was degraded and converted to the SCFAs during food waste fermentation, mass balance of APG in anaerobic fermentation system (liquid + solid phases) was investigated and the results were shown in Table 2. Different from the chemical surfactants, the biosurfactant APG was biodegradable. So it was consumed from the beginning of fermentation and exhausted at the fermentation time of day 15. Compared with the amount of food waste, the dosage of APG added (0.2 g/g TS) was very low in this study. APG can indeed be hydrolyzed and degraded in fermentation process, but its contribution to the SCFA production was very limited. As shown in Table 2, the highest SCFAs production induced from the APG (0.2 g/g TS) were only 121 mg/L, which was much less than that from food waste fermentation (more than 37,200 mg/L). Therefore, although APG was degraded during the anaerobic fermentation, the contribution of APG decomposition to SCFAs production was negligible and most of SCFAs produced was from the biodegradation of food waste.

Table 2
Degradation of APG and its contribution to SCFAs production from APG with fermentation time.[a]

Time (d)	APG content (g/g TS)	SCFAs production (mg/L)
1	0.16 ± 0.03	76 ± 2
2	0.12 ± 0.02	92 ± 4
4	0.08 ± 0.01	104 ± 3
8	0.03 ± 0.01	115 ± 5
12	0.02 ± 0.01	119 ± 6
15	0.00 ± 0.00	121 ± 8

[a] The initial APG was 0.2 g/g TS. Error bars represent standard deviations of triplicate determination.

4. Conclusion

SCFAs production from food waste anaerobic fermentation was significantly enhanced by APG. The maximal SCFAs production was 37.2 g/L when APG dosage was 0.2 g/g TS and the fermentation time was day6. The mechanisms study revealed that the presence of APG accelerated the solubilization and hydrolysis, enhanced the acidification but inhibited methanogenesis, thereby improving the SCFAs production. In addition, the great promotion of key enzymes activities responsible for SCFAs production by APG further confirmed the enhanced mechanism.

Acknowledgements

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