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a homogeneous waste composition that is representative for the kitchen waste in Canada and North America based on the Canadian Food Guide and the USDA Food Patterns [8-10]. e simulated OFMSW used in this study consists of bread (6 wt%), cooked rice (12 wt%), cooked pasta (12 wt%), apples (11 wt%), bananas (11 wt%), cabbage (11 wt%), carrots (11 wt%), ground beef (10 wt%), sh (10 wt%), and boiled eggs with shells (6 wt%). All waste components were prepared fresh and mixed in a food processor to generate a particle size ranges from 1 to 5 mm prior to use. e prepare phis(o)-9 (d p)12 (r)13 (os r)13 (ep)127 (V)33 ase (r)13 (e f)96 (e)0.5 (s8 (en)4 a)9 id 5 (A) [(d)1

e 50:50 ratio (based on TVS) for the TWAS:OFMSW mixture was used in our experiments as recommended by Liu et al. in order to get the best synergetic e ect of OFMSW in the co-digestion process and avoid ammonia accumulation that may occur when high OFMSW concentrations are used in the co-digestion mixture [11].

Analytical methods

e analysis for the BMP assays was done in triplicates, using standard methods [12]. Total and volatile solids were determined according to standard method 2540G. Alkalinity analysis was measured based on standard method 2320B using a Fisher Accument® XL25 pH meter. Biogas was measured using a manometer every 24 hour the rst 7 days of the experiment and it was measured occasionally a er the biogas production slowed down until the end of the BMP assay (40 days). e volume of the biogas was corrected to the standard ambient temperature and pressure conditions (STP, 25°C and 1 atm). e net biogas volumes for samples were calculated by subtracting the biogas produced in the inoculum bottles from the biogas produced in each of the samples bottles. e biogas composition (methane%) was monitored weekly using a Hewlett Packard 5710A gas chromatograph.

Data analysis

e reaction curve model (RC) was used for the non-linear regression to evaluate the anaerobic digestion performance and estimate the lag phase time (λ), predict the ultimate cumulative biogas yield (B_0, mL/g TVS), and nd the maximum biogas production rate (R_m, mL/gTVS.h) for each of the BMP conditions tested in this study. e RC model represented by Equation 1 has been used successfully in literature for anaerobic digestion evaluation [4,13].

$$B = B_0\left[1-\exp\left(-\frac{R_m(t-\lambda)}{B_0}\right)\right] \quad (1)$$

where, B_0 is the ultimate biogas yield (mL/g TVS), B is the cumulative biogas yield (mL/g TVS), t is incubation time (h), R_m is the maximum biogas production rate (mL/g TVS.h), and λ is the lag phase duration time (h).

e rst-order equation (Equation 2) was used to estimate the apparent hydrolysis rate coe cient (rst-order biogas production rate) (k, h^{-1}) for each of the BMP conditions [14].

$ L $ ‹ : s F? ?P A (2)

where k is the rst-order apparent hydrolysis rate (h^{-1}), B0, B and t have the same de nition as de ned in the RC model above (Equation 1).

Statistical analysis of the collected data included t-test (p-value=0.05), one-way analysis of variance (ANOVA), Pearson correlation index (R^2) and degree of freedom.

Results and Discussion

Biogas production and methane yields

e average biogas production rates and the accumulative biogas production results for all BMP assays are illustrated in Figures 1a and 1b, respectively. In addition to Table 3 that represents the average biogas productions, methane contents, methane yields and the improvement in methane yields compared to the control sample TWAS(T).

Comparing TWAS:OFMSW (T) sample with the control sample TWAS(T) in order to evaluate the e ect of 50% (w/w, based on TVS) OFMSW as a co-subsss0TJ 0.1ue5.9 (h)3 p]TJ 0.2 (a)3Tm (2)Tj 9 0 0 mredopTan4 (dw(b)12 (ioga)ne)4 (l1)-3w 0 -nic.1 (e e)

It could be noticed from Table 4 that the control sample TWAS(T) had 11 h estimated lag phase time before starting the biogas production. However, the thermophilic co-digestion sample TWAS:OFMSW(T) had 17.9 h estimated lag phase time. is increase in the lag phase of TWAS:OFMSW(T) sample compared to the control sample TWAS(T) is probably because the inoculum used in the BMP assays was not acclimated to OFMSW as mentioned previously, so microorganisms required longer time to start the AD process. As regards the hyper-thermophilic co-digested samples, it is evident that all hyper-thermophilic digested samples had shorter lag phase time compared to the thermophilic digested samples. Comparing TWAS:OFMSW(H) sample with TWAS:OFMSW(T) sample we can notice the e ect of the 2 days hyper-thermophilic digestion step in shortening the lag phase time from 17.9 h in the thermophilic digestion of TWAS:OFMSW(T) sample to 7.5 h in the hyper-thermophilic digestion of the TWAS:OFMSW(H) sample. is is believed to be due to the solubilization of the co-digestion mixture that occur during the 2 days hyper-thermophilic digestion providing more soluble organic matter that is ready to be utilized by the methanogens in the followed thermophilic part of experiment.

From the results of the maximum methane production rate (R_m ml/g TVS.h) it can be observed that sample TWAS:OFMSW(T) had the lowest R_m value among all other samples. On the other hand the hyper-thermophilic digested sample TWAS:OFMSW(H) had significantly higher R_m compared to TWAS:OFMSW(T) sample. FOG addition clearly boosted the R_m of the three s-7og me ts of the ma7SW nogrl9 [(5) it ce pmf 9(e 4 0 618.4.5(t)-5.9(wau)12.6(h)4(1(n)3(S:O)9(FMSW(
2e9 uu 5.5 0 a d raiogmd ra7.9(d ts u)12.a7c0.5(ReSW cid [(Fh)4(123k8(Gf(e9.91-5(l)12(ts o2477 E-3 Tm [( ) s)-3.4. Tm