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PHYSICAL AND CHEMICAL ANALYSIS OF CANTEEN WASTES FOR SYNGAS PRODUCTION

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This paper studies the physical and chemical properties of different types of food substance generally involved in the daily menu of a university canteen. The data obtained from proximate analysis (i.e. elemental composition, moisture and ash content) suggest that the tested food samples are suitable for synthesis gas production but should be mixed with dry matter from additional resources to make the process commercially viable.

Keywords: canteen waste, synthesis gas production, proximate analysis

Introduction

Apart from discarded food, considerable amounts of food processing or kitchen waste (i.e. remains from meal preparation) are generated in the daily practice of canteens. These are often disposed of as municipal waste in landfill sites. An economically beneficial alternative to landfill disposal is the energy utilization of food waste. Different technical solutions are available: biogas production (through biodegradation), combined waste incineration and synthesis gas production by pyrolysis/gasification.

A detailed study on the physical-chemical properties of canteen waste helps predicting whether the given feedstock/raw material is suitable for thermochemical conversion.

The exhaust gases produced from the pyrolysis/gasification process can be utilized directly as a fuel or, subsequent to purification, as a secondary raw material for the chemical industry. Therefore, the thermal conversion of food and canteen waste is likely to be of considerable economic importance in the long run.

Continuous feedstock supply is one of the most critical factors in the smooth operation of a syngas process plant (besides high initial investment costs). Considering the limited availability of food waste, it seems necessary to combine this feedstock with complementary raw material sources.

1. Synthesis gas production

Synthesis gas is a special gas mixture produced from the thermochemical conversion (pyrolysis, gasification) of different fuels like coals, biomass or wastes. It consists primarily of carbon monoxide and hydrogen (and to a lesser extent other organic components). Industrially generated syngas is target for various uses by the energy industry and the chemical industry, as illustrated in Figure 1 [1].

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The actual composition of the synthesis gas depends on the initial material, the gasifying medium, the time spent by the feed in the distinctive gasification zones and on process temperature and pressure. Relative to these factors, various pollutants may occur in the produced gas, which need to be removed lest they would cause adverse effects during industrial use.

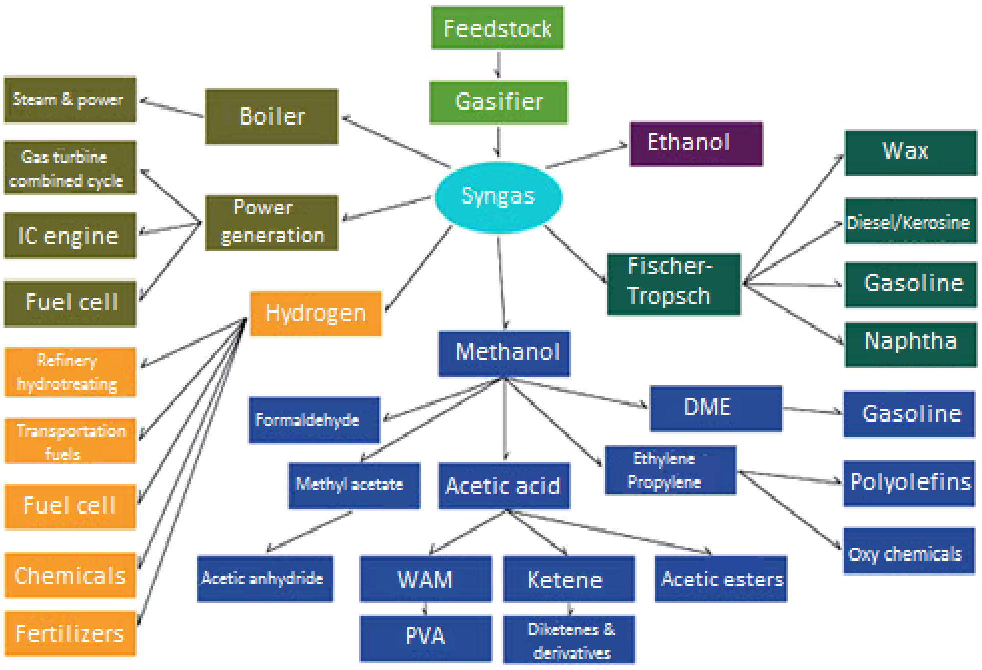

Figure 1. Flow chart of industrial syngas use

2. Materials

It is well-known from the literature that food materials (meat, vegetables, fruits etc.) are basically made up of water, fats, proteins and carbohydrates (Table 1). These building blocks can be broken down into elemental components like carbon, hydrogen and oxygen, which combine into the hydrogen and carbon monoxide fractions of the process gas.

Table 1

Basic parameters of food materials (expressed in weight percent) [2, 3, 4]

Parameter		**Quantity**
Moisture content	%	60–90
Oil or fat content (relative to dry matter)	%	0,1–50
Proteins (relative to dry matter)	%	0–41
Carbohydrates (relative to dry matter)	%	0,1–80

The parameters of ready-made dishes substantially differ from that of the initial food substances (particularly in moisture and oil/fat content). The scarcity of literary data on the elemental composition of prepared meals made it necessary to conduct investigations and lay the base – by ways of quantitative analyses – for experimental syngas production.

Due to excessive water content, soups were precluded from the experiments – only main courses were tested. The samples selected for testing were meals that occur on a daily base in university canteens, e.g. stews, fried and cooked meats, side dishes.

The data were first locally evaluated, then placed in a wider context. Estimates on the provision of feedstock were necessary to investigate the large-scale applicability of the proposed method (i.e. the pyrolysis/gasification of food waste in). Since the remains of ready-made food are not available in large enough quantities for industrial production0 – in Hungary, the total amount of canteen waste is about 220,000 tonnes per year [5] – supplementary raw material resources (like food preparation wastes) should be added to make gasification economically viable.

Subsequent to representative sampling, moisture content was determined using a Mettler Toledo HB43-S type moisture analyser. The samples were dried at a temperature of 105 °C until weight constancy was reached.

The dry samples were then pulverized in a mortar and loaded into a Carlo Erba EA 1108 type elemental analyser for compositional determination. The measurement method was based on the complete and instantaneous oxidation of the samples by flash combustion (thereby organic and inorganic substances could be converted into combustion products). The resulting combustion gases passed through a reduction furnace and were swept into a chromatographic column by the carrier gas (helium). The gas species (CO2, H2, N2, H2S) were separated in the column and detected by a thermal conductivity detector which gave an output signal proportional to the individual components of the mixture.

Finally, ash content was determined by heating the pulverized samples up to 830 °C in an electrical furnace. After being kept at constant temperature for 3 hours, the combusted samples were cooled in a desiccator, then weighed. From the obtained measurement data, weight loss was calculated.

3. Analysis results

The moisture content of the ready-made food samples are represented in Figure 2. The results of elemental analysis and ash content values are summarized in Table 2.

As seen from Figure 2, the moisture content of the distinctive food samples tended to vary on a wide range (23.4-85.4%). The measured values gave a mean average of 59.6%, which was assumed too high to effectuate reasonable syngas yields. Low moisture is critical for process performance, since most thermochemical reactions take place once the water has evaporated from the feed.

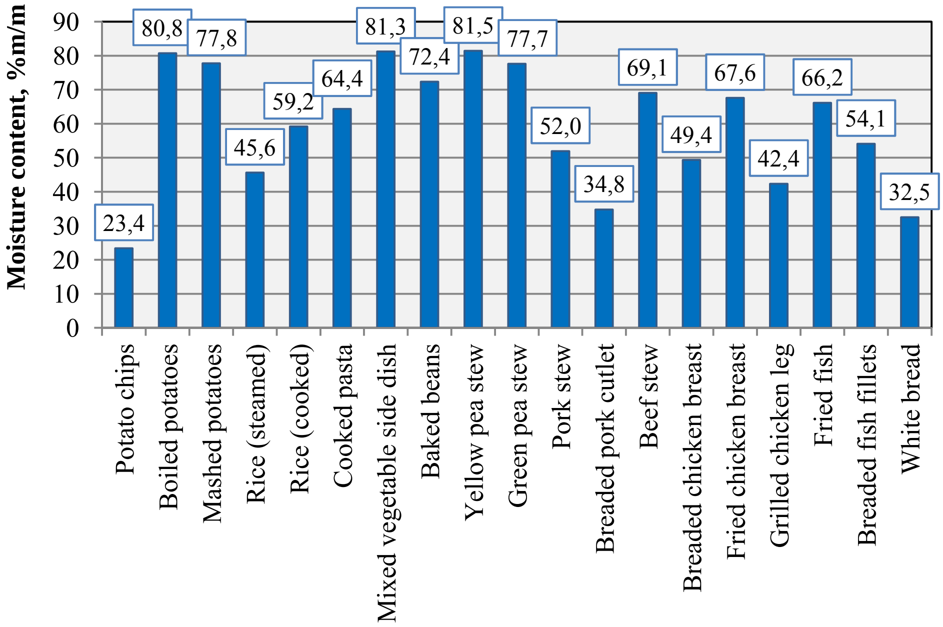

Figure 2. Percent moisture content of ready-made meals

Table 2

Ash content and elemental composition of dry food waste samples

Samples	**Elemental composition of dried samples, %m/m**					**Ash content, %m/m**
	Nitrogen	**Carbon**	**Hydrogen**	**Sulphur**	**Oxygen**	
Potato chips	0.56	43.97	7.58	0.08	44.80	3.01
Boiled potatoes	2.00	36.67	6.53	1.66	49.81	3.33
Mashed potatoes	1.41	44.48	7.29	0.91	42.46	3.45
Rice (steamed)	1.13	41.13	6.90	1.58	48.10	1.16
Rice (cooked)	0.70	42.08	7.01	1.98	47.04	1.19
Cooked pasta	2.24	42.97	7.00	2.06	44.52	1.21
Mixed vegetable side dish	2.10	40.44	8.66	2.13	42.43	4.24
Baked beans	3.18	43.26	6.76	2.01	40.46	4.33
Yellow pea stew	2.76	42.56	7.05	2.11	43.08	2.44
Green pea stew	2.30	44.16	7.38	1.84	41.30	3.02
Pork stew	8.23	52.74	7.87	0.94	26.91	3.31

Samples	**Elemental composition of dried samples, %m/m**					**Ash content, %m/m**
	Nitrogen	**Carbon**	**Hydrogen**	**Sulphur**	**Oxygen**	
Breaded pork cutlet	5.74	53.91	8.25	3.25	26.91	1.94
Beef stew	13.53	46.22	9.18	2.72	24.02	4.33
Breaded chicken breast	6.18	49.50	7.75	2.83	30.56	3.18
Fried chicken breast	13.30	48.48	9.59	2.68	20.77	5.18
Grilled chicken leg	7.89	53.31	8.35	3.48	23.77	3.20
Fried fish	12.91	49.69	9.50	3.12	19.33	5.45
Breaded fish fillets	8.19	51.45	10.17	2.99	23.25	3.95
White bread	1.90	44.02	7.07	2.80	42.65	1.56
Average	**5.07**	**45.84**	**7.89**	**2.17**	**35.90**	**3.13**

The following conclusions can be drawn from Table 2:

The carbon content of the samples (40–50%) should allow for the pyrolysis/gasification reactions. Average oxygen content (35.9%) seems also favourable. The carbon to oxygen ratio of the raw material stream would facilitate the formation of carbon monoxide under optimal conditions. The measured amounts of H would be processed into H_2, constituting the second main combustible fraction of syngas. The pyrolysis/gasification of food waste might produce some undesirable products. Highly corrosive, toxic gases like hydrogen sulphide (H_2S) – formed from the sulphur compounds found in the feed – should be removed from the raw syngas stream prior to industrial utilization. Considering the low measured amounts of sulphur in the tested samples (<3%), only a minimal level of H_2S is expected to actually occur in the syngas. Another potential source of impurities is ammonia generated from the initial nitrogen content of the raw material. Once detected, this compound should also be removed from the syngas to prevent adverse, harmful effects.

The most commonly applied fuel for syngas production is coal. Comparing the ash content of coals (as given in the literature [6, 7]) to that of the tested food materials, 5 to 10 times lower values were obtained for the latter. Consequently, the expected amount of solid burning residues (slags) from the pyrolysis/gasification experiments is also estimated to be low.

Table 3 shows the ash content and compositional data obtained for vegetable residues generated during the food preparation processes. Percent moisture contents are illustrated in Figure 3.

Table 3

Ash content and elemental composition of vegetable residues (dry samples)

Samples	Elemental composition of dried samples, %m/m					Ash content, %m/m
	Nitrogen	**Carbon**	**Hydrogen**	**Sulphur**	**Oxygen**	
Withered cabbage	3.85	42,00	5.48	1.23	38.16	9.28
Dry garlic	2.28	42.20	5.90	0.76	42.69	6.17
Clementines peel	1.27	41.94	6.51	<100 ppm	47.39	2.89
Withered potato skins	2.32	42.09	6.23	0.42	44.55	4.39
Onion skins	1.68	25.28	4.92	0.70	60.93	6.49
Withered apple	0.34	39.33	6.69	<100 ppm	52.42	1.22
Withered carrot	1.41	40.32	4.84	0.29	47.30	5.84
Orange peels	0.91	44.00	6.15	<100 ppm	46.95	1.99
Banana peels	0.87	40.60	5.36	<100 ppm	43.75	9.42
Withered turnip	2.06	40.80	5.09	0.36	45.93	5.76
Kohlrabi peels	1.89	39.96	4.68	0.51	45.45	7.51
Capsicum leftovers	2.67	41.60	5.14	0.40	41.93	8.26
Withered lettuce	3.58	56.64	5.75	0.21	24.95	8.87
Cucumber peels	3.32	52.40	6.23	0.12	29.29	8.64
Radish peels	3.63	44.78	5.88	0.15	35.81	9.75
Average	**2.14**	**42.26**	**5.66**	**0.34**	**43.17**	**6.43**

As seen from Table 3, the average carbon content of food preparation wastes fell by 3.5% below the carbon measured for the food prepared. Yet, it was associated with higher oxygen content. The percent values of nitrogen and hydrogen were higher than for ready-made dishes, while significantly less sulphur was measured (0.34% on average). The ash content of the tested samples was twice as much as in Table 2.

Percent moisture content was about 15% higher for vegetable residues (food preparation wastes) than for prepared food material. The comparative results are represented in Figures 4 and 5.

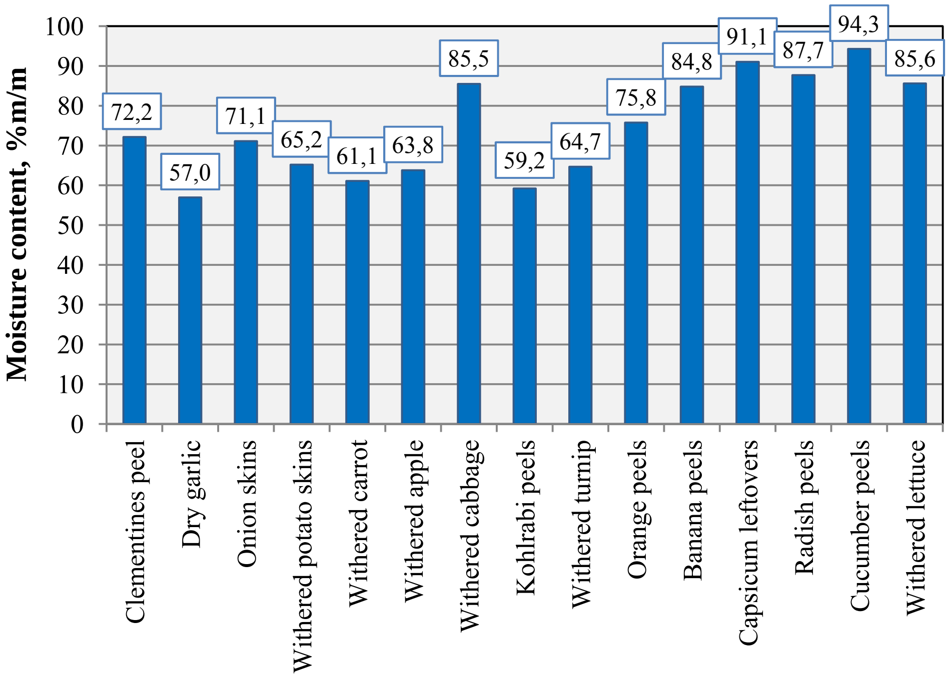

Figure 3. Percent moisture content of vegetable residues (from food preparation)

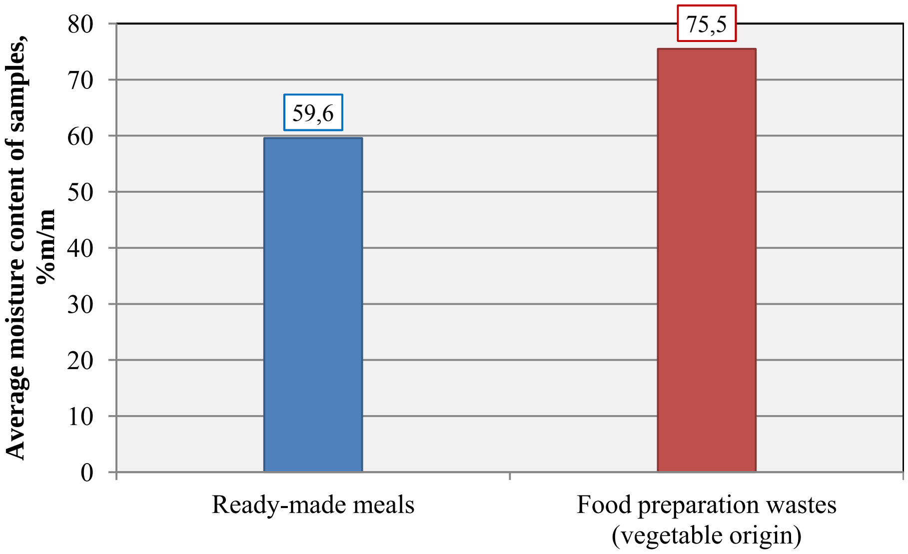

Figure 4. Average moisture content of ready-made meals and vegetable residues

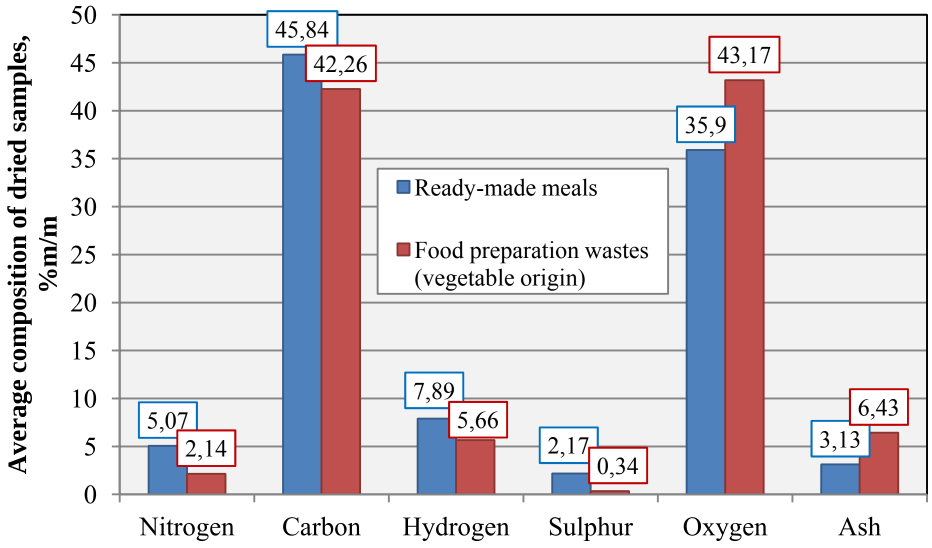

Figure 5. Average composition of ready-made meals and vegetable residues

Conclusion

Food wastes include any food substance that is discarded or unfit for human consumption, primarily generated by commercial establishments involved in the food supply chain, such as food processing plants, storehouses, caterers and retail premises.

This paper focuses on the study of canteen wastes. Canteen wastes come from a variety of sources:

- restaurants and cafeterias
- employee lunchrooms, and school canteens
- institutional and communal kitchens
- catering services, mobile catering
- kitchens of snack bars and fast food restaurants
- refreshment rooms

Proximate analysis was conducted to determine the elemental composition, moisture and ash content of ready-made dishes prepared on a daily base in a university canteen, and of food preparation wastes of vegetable origin.

Based on the results, both tested waste groups were found to meet the basic compositional criteria for syngas production. However, high moisture levels and limited feedstock availability justifies the need for economically advanced and technologically viable solutions, like the combined application of food waste and other material streams in the pyrolysis/gasification process. Complementary dry matter sources can be specified from the actual performance data of the pyrolysis/gasification experiments.

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