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Analytical Test of Water-Extract from Fermented Ground Maize as an Alternative Base for Engine Coolants

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Abstract

Existing water-based engine coolants (WBEC) are produced by adding corrosion inhibitors (CI) and anti-freezing agents (AFA) to de-ionized water. Water is first deionized to remove corrosion factors (CF) before the additives are introduced. This study seeks to determine whether water-extract from fermented ground maize (WEFGM) can be a better alternative to water for the production of WBEC, on account of the additives. WEFGM was analyzed for CI, CF and AFA. Two samples of WEFGM, decanted from kewesoke (white) and western yellow varieties of maize, were used. In the analysis, atomic absorption spectrometry and other methods were used for CF; colorimetric methods using a spectrophotometer was used for CI, and gas chromatography/flame ionization detection (GC/FID) was used for AFA. The result for CF in the 2 samples, respectively, revealed pH values of 2.82 and 2.67, conductivity of 1941 and 1786 µs/cm, Pb of 0.06 and 0.05 mg/L, and Zn of 0.74 and 0.89 mg/L. CI found were 12.25 and 22.51 mg/L of phosphates and 5.00 and 6.00 mg/L of nitrates, while AFA obtained were 5.29 and 2.38 mg/L of ethylene glycols and 4.74 and 2.15 mg/L of propylene glycols from the 2 samples, respectively. There was no significant difference in these properties for the two samples ($P < 0.05$). The detection of CI and AFA in WEFGM prospectively makes it a more cost-saving base fluid for WBEC than water.

Keywords: Water-extract, fermented maize, glycols, engine coolant, corrosion

Introduction

Water is regarded as the best heat transfer fluid because of its availability and biodegradability. However, engine coolants must also be anti-freezing, while water has a low freezing point. They must also be corrosion resistant, while water is also made up of ions and various minerals which are responsible for corrosion. It is for this reason that water itself is not perfectly suitable as an excellent engine coolant.

Therefore, existing water-based engine coolants are produced by adding corrosion inhibitors and anti-freezing agents (mainly ethylene and propylene glycols) to deionized water. Water is first deionized to remove corrosion factors before the additives are introduced. These supplemental compounds make engine coolants more expensive. Hence, there is the need for further research on an alternative, which has certain percentages of these compounds such that, when also deionized, it can be a cost-saving substitute for water. This development brings water-extract from fermented ground maize (WEFGM) into focus. Being organic waste product, WEFGM is cheaply available and biodegradable like water.

It is therefore worthy of being analytically studied for relevant constituents. These include the anti-freezing agents (AFA) and corrosion inhibitors (CI) which are used as supplements in water to make water-based engine coolants, as well as the corrosion factors (CF) that would need to be deionized and/or dissociated therefrom. Based on the assertions of [1], that ethylene glycol has been discovered in certain foodstuffs, and [2], which reported corn as being one of the emerging renewable sources of propylene glycol, the detection of glycols in WEFGM is of high probability. More so, Yusuf *et al*. [3] has remarked that little or nothing has been done by previous researchers in utilization of this organic water in technology and engineering.

Statement of the problem

Existing engine coolants are expensive. This high cost of procurement is largely due to inorganic constituents used in its production, which are mainly anti-freezing agents (glycols) and corrosion inhibitors. This has forced many Nigerian automobile users to improvise with ordinary water, which is less effective. Water has a high tendency for corrosion, as well as a low freezing point. Apart from the rigor and high cost of their production, research has shown that glycols are very lethal. Hence, there is the need for an alternative source of these coolant constituents on economic and safety grounds.

Literature review

A coolant is a fluid which flows through or around a device to prevent overheating and then transfers the heat produced by the device to other devices that use or dissipate it [4]. It also serves to prevent freezing and, most importantly, provides protection from corrosion [2]. An ideal coolant has high thermal capacity, low viscosity, and low cost, and is non-toxic and chemically inert, neither causing nor promoting corrosion of the cooling system [4].

According to [5] and [6], engine coolants are commonly based on ethylene glycol (1,2 ethanediol) or propylene glycol (1,2 propanediol). These 2 compounds have offered the lowest-cost chemical bases for engine antifreezes/coolants for several decades [7]. Anand [4] has also reported that engine coolants are primarily composed of 3 items, namely: glycol (ethylene or propylene), deionized water, and corrosion inhibitors. The author also remarked that the differences between engine coolants depend basically on the quality of each of these components. The primary function of the glycols in coolant is protection against freeze, even though water provides the best heat transfer [8]. FAL [9] has reported that antifreeze solutions in automobile coolants typically have an ethylene glycol content of 50 %. The presence of ethylene glycols has also been reported in other automobile fluids, such as brake fluid [10] at a quantity below 0.1 %.

Comparing the 2 glycols, researchers have found out that propylene glycol is less toxic and more environmentally beneficial than ethylene glycols. Nevertheless, ethylene glycol is more widely used in coolant [2]. The author listed lower viscosity, higher density, and better thermal conductivity as its superior features. According to the same author, despite its environmental benefit, propylene glycol is very expensive, and also comes from a non-renewable source, but emerging development is providing renewable sources from corn and biodiesel processes.

As for corrosion inhibitors, they are additives in coolants that inhibit corrosion and scale formation in the engine cooling system [11]. Corrosiveness is a function of concentration of corrosive ions, such as chloride and sulfate [12]. According to [13], corrosion inhibitors fall into many general classes, like phosphates, silicates, and organic acids. Coolant additives may include organic acids, silicates and phosphates, nitrites, defoamers, and bittering agents [14]. Qun and Lang [15] also listed silicates and phosphates as commonly used inhibitors, and together with others like molybdates and tungstates, they form the inhibitors in many recent patents [16]. While all these inhibitors, including borates, are from inorganic sources, organic products such as carboxylates are key components in the additive package of Organic Additive Technology (OAT) coolants [17].

Materials and methods

Source of materials

Maize grains (*Zea mays L.*) were used for the study. The kewesoke (white) and western yellow varieties of the grains were bought from Osiele market in Abeokuta, Ogun State, Nigeria.

Sample preparation

White and yellow samples of WEFGM were produced separately using the fermented procedure method described by [18]. The modified and adapted diagram of this procedure is shown in **Figure 1**. They were then kept separately in 2 white 5 liter kegs in the laboratories.

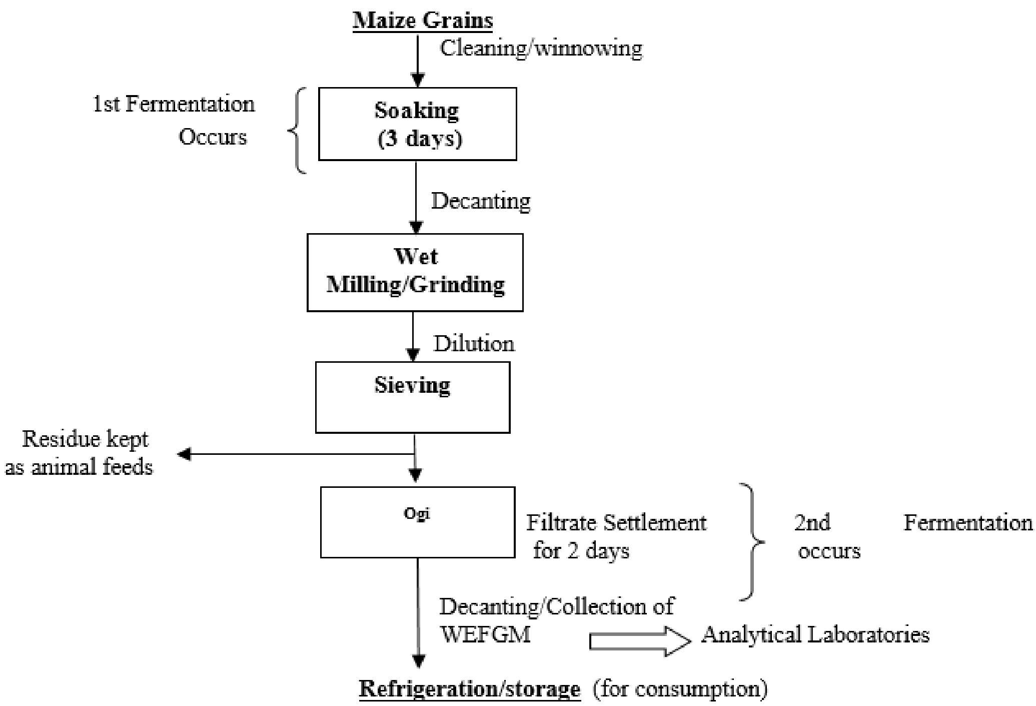

Figure 1 Process diagram for WEFGM production.

Analytical laboratories

Analytical tests for minerals, bacteria, and other physicochemical properties were done at the following locations:

(i) National Institute of Science and Laboratory Technology (NISLT), Samonda, Ibadan Oyo State, Nigeria. This is a standard scientific research institute established by the Federal Government of Nigeria.

(ii) Alfa Laboratories Limited (Public Analysts, Industrial Chemists and Environmental Consultants), JOAS House, Amuwo Odofin Industrial Estate, Lagos State, Nigeria. This is one of the most well-known registered private standard analytical research laboratories in Nigeria.

Analytical methods and parameters

Methods for corrosion factors

The standard analytical methods used in determination of each of the specific corrosion factors are presented in **Table 1**.

Table 1 Physicochemical characteristics and methods of determination.

Parameters	Methods
PH	Electrometric
Electrical Conductivity	Meter
Total Dissolved Solids	Dried at 103 - 105 °C
Hardness	EDTA Titrimetric
Copper	AAS- Direct Air-Acetylene Flame
Aluminum	Eriochrome Cyanine R
Magnesium	EDTA Titrimetric
Iron	Atomic Absorption Spectrometry (AAS)- Direct Air-Acetylene Flame
Calcium	Digestion and Flame Atomic Absorption (FAA)
Zinc	Atomic Absorption Spectrometry (AAS)- Direct Air Acetylene Flame
Lead	Atomic Absorption Spectrometry (AAS)- Direct Air-Acetylene Flame
Bacterial (Total Coliform)	Multiple Tube Fermentation Technique

Methods for corrosion inhibitors

The analytical method used for the determination of phosphates and nitrites, as presented by NISLT, is the Colorimetric Method, using a Spectrophotometer.

Methods for anti-freezing agents

The anti-freezing agents, ethylene, and propylene glycols were analyzed by Alfa Laboratories using a gas chromatography/flame ionization detector (GC/FID), with the description presented in **Table 2**.

Statistical analysis

Following the outcomes of the entire experimental procedures, the data obtained were statistically analyzed using IBM SPSS statistics software version 21. A conclusion was then made on the result of this analysis.

Table 2 Analytical method for glycols.

Method		Gas Chromatography (GC)
Detector		Flame Ionization Detector (FID)
Column		HP-FFAP (Agilent)
Inlet Temperature		175 °C
Detector Temperature		175 °C
Oven Temp	Initial	60 °C
	Final	200 °C
Time	Initial	4.0 min
	Final	2.0 min
Rate		6.0 °C/min
Total Run Time		29.0 min
Reference standard		1000 mg/L of sample (0.1 %)

Results and discussion

Corrosion factors

Analysis of corrosion factors in the samples gives the following result in **Table 3**.

Table 3 Corrosion factors of the samples.

Corrosion factors	Parameters	White WEFGM	Yellow WEFGM
	PH	2.82	2.67
	Hardness (mg/l)	176	124
	Conductivity (µs/cm)	1941	1786
	Total Dissolved Solids (TDS) (mg/l)	907	831
	Alkalinity (mg/l)	Nil	Nil
Minerals	Unit (ppm)		
	Copper, Cu	0.04	0.03
	Lead, Pb	0.06	0.05
	Zinc, Zn	0.74	0.89
	Iron, Fe	1.94	3.31
	Aluminum, Al	ND*	0.01
	Magnesium, Mg	82.5	82
	Calcium, Ca	2.84	3.12
Bacterial	Unit (CFU**/ml)		
	Dilution factor ($\times 10^{-1}$)	40	33
	Dilution Factor ($\times 10^{-3}$)	11	9

*ND = Not detected
**CFU = Colony forming unit

Corrosion inhibitors

Analysis of corrosion inhibitors in the samples gives the following result in **Table 4**.

Table 4 Corrosion inhibitors present in the samples.

S/N	Inhibitors (mg/l)	White WEFGM	Yellow WEFGM
1	Phosphates (as PO_4)	12.25	22.51
2	Nitrates (as NO_3-N)	5	6

Anti-freezing agents

The results of the analytical test for anti-freezing agents in the samples are presented in **Table 5**.

Table 5 Ethylene and propylene glycols in the samples.

S/N	Anti-freezing Agents (ppm)	White WEFGM	Yellow WEFGM
1	Ethylene Glycol	5.29	4.74
2	Propylene Glycol	2.38	2.15

Table 3 shows that WEFGM is considerably acidic, with pH values between 2.82 and 2.67; hard, with hardness values between 124 and 176 mg/L, and has conductivity values ranging between 1786 and 1941 µs/cm. Research has shown that these properties are dependent on another, and must have been influenced by the quantity of total dissolved solids (831 - 907 mg/L), minerals, and microorganisms (bacteria) present. For instance, hardness is due to the presence of dissolved minerals, such as calcium and magnesium [17]. According to the existing standard, the hardness of WEFGM can be said to be moderate or medium (125 - 229 ppm) [19]. It may even be unsuitable referring to WEFGM as hard, since its hardness value is below 300 ppm [19,20]. The more significant prospect of this result is that water with low or no minerals is not suitable for coolants and, consequently hardness below the indicated moderate level can cause a problem [21]. More so, conductivity is the ability of fluid to conduct electricity, which increases as minerals accumulate. So, pure water having no minerals has no appreciable conductivity value [22]. According to previous findings, phosphates and sulphates of above 30 ppm stimulate bacterial growth and, as bacteria multiply, they produce acids which lower the pH [20]. Hence, acidic pH of WEFGM must have been influenced by the phosphates value, as recorded in **Table 4**. It is also possible that this low pH value of WEFGM may be due to the fermentation process, leading to the accumulation of some acids, such as lactic and carboxylic acids [23], which are often present in starchy food products. The same may also be responsible for the identified colliform bacteria, as [24] had reported that the growth of the majority of fungi is favored by an acidic pH. However, T-test shows that there is no significant difference between these pairs of values ($P < 0.05$) for the 2 samples. It has been reported that corrosion is commonly associated with pH levels below 6.5 [25] or 7.0 [26]. Consequently, a pH between 8 and 10 is found to be ideal for cooling [26]. High conductivity and TDS have also been listed as influencing corrosion in coolant delivery systems [27]. For water quality acceptable for effective coolant performance, [27] has recommended a conductivity of < 500 and pH of between 6 and 8. This, however, is not of serious consequence, as deionization, isolation of the bacteria, and adjustment of pH are regular procedures in coolant technology [20]. As water is deionized for the production of water-based engine coolants (WBEC), dissociation or remediation of the detected corrosion factors may be a necessary preliminary procedure for WEFGM before its proposed use for WBEC.

Tables 4 and **5** show that WEFGM contains organic corrosion inhibitors (nitrates and phosphates) and anti-freezing agents (ethylene and propylene glycols), and the respective tests show that there is no significant difference between these values for both white and yellow samples ($P < 0.05$). The CI and AFA are the most essential constituents of an engine coolant. In fact, they are major ingredients, without which WBEC is neither produced nor optimally effective when produced. Eaton *et al*. [7] has recommended inclusion of these compounds in coolant for internal combustion engines. Their presence in WEFGM is its greatest merit over water for WBEC production. Water does not contain these compounds [1]. The result supports the assertions of the same author that ethylene glycols are found in some foodstuffs. This study has added maize to the list of such foodstuffs. It also confirms the report of [2] that corn is an emerging renewable source of propylene glycols.

Conclusions

Minerals, CI and AFA, which are essential constituents in WBEC coolants, were found in WEFGM. After dissociating or remediation of the corrosion factors (CF), the required quantity of these supplemental compounds would be less than that which would be required by deionized water. It is therefore prospectively a more cost-saving alternative base for WBEC than water. More so, it is also free of the challenges of non-availability, non-biodegradability, and toxicity. Meanwhile, the last phase of this study, which would require dissociating some forms of CF from WEFGM and remediation of others, and concluded by comparing WEFGM-based coolant in application with existing WBEC, is recommended.

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