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Evaluation of the self-ignition point of hydro-alcoholic gels sold in supermarkets in Abidjan (Cote d'Ivoire)

Urbain Paul GNONSORO[1] *, Vandjiguiba DIABY[2], Konan Jean-Marie KOUAKOU[1], Ardjouma DEMBELE[1] and Albert TROKOUREY [3]

[1] Laboratoire Central d'Agrochimie et d'Ecotoxicologie (LCAE), Laboratoire National d'Appui au Développement Agricole (LANADA), 04 BP 612 Abidjan, Côte d'Ivoire*

[2]Laboratoire Central pour l'Hygiène Alimentaire et l'Agro-Industrie (LCHAI), Laboratoire National d'Appui au Développement Agricole (LANADA), 04 BP 612 Abidjan, Côte d'Ivoire

[3]UFR SSMT, Laboratoire de Chimie Physique, Université Félix Houphouët Boigny, 22 BP 582 Abidjan, Côte d'Ivoire

**Corresponding author; E-mail: urbainpaulgnonsoro@gmail.com; Tel: (+225) 07440725*

ABSTRACT

Hydro-alcoholic gel using and storage poses a higher risk of fires or injuries due to ignition or self-ignition. The self-ignition temperatures of hydro-alcoholic gels, sold in supermarkets in Abidjan (Cote d'Ivoire), were determined using the isothermal oven procedure and analyzed described in standard DIN 51794. The results obtained throw light on the optimum volume of hydro-alcoholic gel and aluminium tanks to use to self-ignite. The self-ignition temperatures of hydro-alcoholic gel obtained, range from 389 to 446°C with an average of 417.45 ± 14.40°C. This result showed a good agreement with the safety data sheets for some hydro-alcoholic gels. In addition, we found that the temperatures recorded are very high to be reached in closed rooms, even subjected to direct sunlight, such as cars, containers, etc. Therefore, the hydro-alcoholics gels self-ignition temperatures cannot be achieved by use or storage in rooms subject to ambient temperature, except in the case of heat energy source application such as a pilot flame.

Key words: Self-ignition, hydro-alcoholic gel, DIN 51794, temperature, Abidjan

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INTRODUCTION

The start of the 2020 decade is marked by many milestones that escape the predictions and keenest prevision of modern science. Among all events that occur in 2020, the COVID-19 pandemic is the most trouble, because it has upset and affected the stability of many countries around the world [1]. Studies have found that most people with COVID-19 only develop mild or uncomplicated illness [2], while others are asymptomatic (showing no manifestation of this disease). Asymptomatic people, who generally come from groups less at risk (young people in good health, etc.) are also contagious. It is therefore necessary to observe special measures in order to prevent and limit the contamination of people at risk. To do this, most countries, including Cote d'Ivoire, have mobilized material and financial resources to support populations against this pandemic. Among these resources, the production of hydro-alcoholic products on a large scale has been set up in order to participate in the fight against COVID-19 [3].

Indeed, hydroalcoholic products are alcoholic preparations usually containing 60 to 95% ethanol or isopropanol and designed to be applied to the hands in order to reduce the number of viable microorganisms [4]. These are quick-drying hydro-alcoholic products designed specifically for hand disinfection. They contain an emollient and sometimes an antiseptic. They are applied by friction without rinsing the hands. These hydro-alcoholic products fall into the category of type 1 biocidal products, that means biocidal products intended for human hygiene [4]. These products come in several forms including: Hydro-alcoholic solutions, hydro-alcoholic gels, foams, wipes, etc. [5]. Among these products, the hydro-alcoholic gel turns out to be the most used and the most widespread in supermarkets and in the arteries of the city of Abidjan (Cote d'Ivoire), because of its simplicity of use, its rapid drying and time saving, as it does not require water, soap or paper [5]. These hydro-alcoholic gels consist of three types of constituents: The active ingredient (alcohol or isopropanol), water and emollients (glycerin or glycerol) [5]. They are more effective than hand washing with soap and they have good skin tolerance [4]. However, they have some drawbacks, including inactivity against spores and parasites, uselessness on soiled, wet or injured hands, but also flammability which requires certain precautions during their use and storage [6].

Several facts reported in the literature report misuse or improper storage of hydro-alcoholic gels resulting in bodily injury and / or fires [7-9]. The vast majority of these cases arise from an application of a heat energy source such as a pilot flame, however rare, unproven cases report the possibility of self-ignition of the hydro-alcoholic gel due to excessive heat source. The risk of self-ignition in the handling and storage of gels is therefore one of the primary causes of fire and personal injury from these compounds. Indeed, the self-ignition of a compound is considered to be the ignition of this compound in air in general, resulting from the release of heat produced by an exothermic oxidation reaction in the absence of a source external incandescence such as a spark or flame [10-11]. The self-ignition temperature is then defined as the minimum temperature at which self-ignition occurs under the specific conditions of a test [11]. Generally, the self-ignition temperature is considered to be the temperature of a fuel at which the heat given off by the exothermic oxidation reactions of the system will overcome that lost by the Joule effect in the environment [12]. So, Are the hydro-alcoholic gels sold in Abidjan a danger for the consumer? The objective of this study is to assess the self-ignition point of hydro-alcoholic gels sold in supermarkets in the district of Abidjan (Cote d'Ivoire) in order to estimate the potential risk of self-ignition for the populations.

MATERIAL AND METHODS

Sampling

A total of 31 samples of hydro-alcoholic gel from 16 different brands was collected at random in supermarkets of 6 municipalities in the district of Abidjan, which are Abobo, Cocody, Koumassi, Plateau, Treichville and Yopougon. An average of about 5 samples of 100 ml to 500 ml of hydro-alcoholic gel of different brands was collected during the period of August 3 and 12, 2020. After sampling, the collected gels were named with an unique number identifier and quickly transported to the Laboratoire Central d'Agrochimie et d'Ecotoxicologie (LCAE), a unit of the Laboratoire National d'Appui au Développement Agricole (LANADA), Abidjan (Cote d'Ivoire) for analysis. In the laboratory, the 31 samples of hydro-alcoholic gels were stored at room temperature, protected from light, and the analyzes were carried out within a period not exceeding 5 days.

Work Material

The working equipment used in this study consisted of around thirty samples of hydro-alcoholic gels from 16 different brands (Figure 1), a Sartorius precision balance, a muffle oven from 30 to 3000 °C brand Nabertherm, aluminum tanks with volume of 100, 150 and 200 cm^3 as well as graduated test-tubes of volume 100, 250 and 500 ml.

Fig. 1 Photograph of samples of hydro-alcoholic gels of different brands

Détermination of the Self-ignition Point

The self-ignition temperatures of the various samples of hydro-alcoholic gels were determined using methods based on DIN 51794 [13]. The analysis is based on different heating volumes of test material at a constant temperature in an isothermal oven. The aim is to determine the self-ignition temperatures of these different volumes, so that the extrapolation of the results can identify the minimum volumes to obtain self-ignition. The Nabertherm brand muffle oven (Figure 3) used has an internal volume of 18.15 L (37.5cmx22cmx22cm) and can reach a temperature of 3000 °C

The self-ignition temperature was measured by introducing, in the oven at temperatures ranging from 30 to 550 °C, different volumes of hydro-alcoholic gels in different sizes of aluminum tanks to determine the optimal volume of gel to pour according to the size of the aluminum tanks. The choice of aluminum tanks is justified by the high melting temperature of aluminum, which is around 657 °C [14]. The hydro-alcoholic gel samples were poured into aluminum tanks of different sizes (volume of 100, 150 and 200 cm^3), open at the top and closed at the bottom. The volumes of hydro-alcoholic gels used in this study were 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 ml. A sufficient number of trials were carried out with a different volume of hydro-alcoholic gel on each size of tank, until the volume of gel was sufficient to cause self-ignition. These different volumes were measured to remain in conformity with the conditions presented by standard DIN 51794 [13].

RESULTS AND DISCUSSION

Optimal conditions for hydro-alcoholic gels self-ignition

The study of optimal volume of hydro-alcoholic gel and size of aluminum tank that could lead to self-ignition led to the results below (Table 1).

Table -1 Self-ignition temperature as a function of the volume of hydro-alcoholic gels and the volume of the aluminum tanks

Volume of hydro-alcoholic gel (ml)	**Volume of aluminum tanks (cm^3)**		
	100cm^3	**150cm^3**	**200cm^3**
10	-	-	-
20	-	-	-
30	473	454	-
40	459	452	-
50	456	443	442
60	447	444	408
70	453	460	397
80	449	452	402
90	451	464	394
100	442	443	395

-: Self-ignition not observed

The results presented in Table 1 show that the self-ignition of the hydro-alcoholic gels was observed from a volume of 30 ml for the tanks of 100 cm^3 and 150 cm3, while for the tank of 200 cm^3 a minimum of 50 ml of hydro-alcoholic gel was required to observe self-ignition. These results highlight the real impact of the minimum vapors required to produce self-ignition of the hydro-alcoholic gel. It also showed the shape of the tank and the volume of gel necessary to observe the phenomenon of self-ignition. Observation of the average self-ignition temperatures as a function of the gel volume and the volume of the tank used (Table 1) show a marked reduction in the self-ignition volume for the same hydro-alcoholic gel. For the 100 cm^3 aluminum tank, the average self-ignition temperatures range from 473 to 442 °C as the gel volume increases from 30 to 100 ml. In the 200 cm^3 tank, the average self-ignition point varied between 442 and 394 °C for a hydro-alcoholic gels volume variation from 50 to 100 ml, while for the 150 cm^3 tank the average point self-ignition decreased from 454 to 443 °C for a change in gel volume between 30 and 50 ml, followed by a non-uniform change in the average self-ignition temperature from around 443 to 464 °C during increasing the volume of hydro-alcoholic gel from 50 to 100 ml. The average self-ignition temperature of the gels therefore decreases when the gel volume and the volume of the tank increase from 100 to 200 cm^3 aluminum tanks. On the other hand, for the 150 cm^3 tank, after a reduction in the average self-ignition temperature between the volumes of 30 to 50 ml, it is distributed unevenly upwards from a volume of 50 ml of gel. In view of these results, and given the differences between the tanks (the 200 cm3 tank is parallelepiped, while those of 100 and 150 cm3 are cylindrical) we can extrapolate that the shape and the volume of the tank greatly influence the reached of the self-ignition point. Tanks with a more evasive shape allow the gel to evaporate faster and lead to a lower self-ignition point, while smaller-volume cylindrical tanks lead to a higher self-ignition point. These results clearly reflect a correlation between the volume of the tank and the volume of gel used to obtain self-ignition. These results corroborate the studies carried out by J. García-Torrenta et al. [15], Álvaro Ramírez et al. [16] And Dejian Wu et al. [17] who studied the self-ignition of different types of coal and biomass, dust generated by agricultural feedstock and that of coal dust accumulation respectively. The work of these authors has in fact also demonstrated a reduction in the self-ignition temperature, inversely to the increase in the volume of the tank and that of the study matrix. Also, the self-ignition observed in the present study could undoubtedly come from ethanol, the main constituent of the gel with water and glycerin [5]. Since ethanol is very flammable, the ignition of gel samples could only result from the high flammability of ethanol, which has an self-ignition temperature between 423 and 425 °C [18-19]. Indeed, ethanol is very volatile (boiling temperature around 79.4 °C [19]), its low boiling point combined with a rapid rise in the temperature of the vapors in the oven could justify the self-ignition of the hydro-alcoholic gels and the precautions to be taken during its use or storage.

In view of these results, the minimum self-ignition temperature was obtained for the 200 cm^3 tank regardless of the volume of gel used (Table 1). The optimal conditions for achieving self-ignition of the hydroalcoholic gel in this study were set for the use of the 200 cm^3 aluminum tank and a volume of hydro-alcoholic gel of 70 ml. The choice of the volume of 70 ml is justified, by the increasingly increased availability of hydro-alcoholic gels, in the large area of Abidjan, in so-called portable and practical formats which are highly appreciated by populations with volumes varying from 60 to 80 ml.

Fig. 1 Self-ignition photograph of a hydro-alcoholic gel in a muffle oven (author source)

Self-ignition temperatures of hydro-alcoholic gels

The experimental device used made it possible to measure the self-ignition temperatures of the hydro-alcoholic gels given by direct reading on the display of the oven by the operator. Two other parameters could be considered, the pressure and the apparent heat release. The work carried out by Catherine ALIGROT [20] on the experimental and theoretical study of the self-ignition delay of different fuels in a combustion room at constant volume showed that the impact of the apparent heat release is lower than those of the pressure, while the direct reading impact is slightly greater than the other two impacts. The influence of the initial pressure on the self-ignition temperature does not seem very marked (Catherine ALIGROT, [20]). This result justifies the fact that this study was carried out at atmospheric pressure and the self-ignition temperatures were determined by direct reading on the display of the oven. Also, to minimise the impact of the initial heating temperature of the oven on the self-ignition characteristics, impact noted by Catherine ALIGROT [20], the studies were carried out at ambient temperature located around 30 °C. Indeed, high initial temperature could reduce the self-ignition temperature, notably by improving the gel evaporation process and the chemical process, by accelerating the reactions leading to self-ignition.

Thus, the optimal self-ignition conditions obtained in the previous section were applied to the 31 gel samples collected in supermarkets in Abidjan. The self-ignition temperatures of the gels obtained at the end of these tests are presented in Figure 3 below. The self-ignition temperatures obtained are in the range of self-ignition temperatures of gels indicated in the literature and set between 400 °C and 425 °C [21-23]. In fact, the self-ignition temperatures obtained at the end of this study varied between 389 °C and 446 °C with an average of 417.45 ± 14.40 °C (Figure 3).
The thermal stability tests (such as those described by standard DIN 51794 [13]) carried out in this study aimed to evaluate the self-ignition points of samples of hydro-alcoholic gels collected through several supermarkets in Abidjan. These tests made it possible to study products that are very flammable, because they contain ethanol which is prone to self-ignition. The self-ignition temperatures obtained, values between 389 and 446 °C, are very high to be reached in closed rooms, even subjected to direct sunlight, such as cars, containers, etc., unless whether they are ovens. The example of the maximum temperatures recorded, between 59 and 78 °C, in closed vehicles [24-25] is very edifying. The temperature reached in containers because of the sun will depend on the time of year, whether the container is made of steel or prefabricated, whether isolated or in group of containers, etc. In addition, the method of storing the hydro-alcoholic gel in bulk or in a tidy manner, something which could influence the evaporation of the gel into the air, is not very important, because the gel is almost always stored in plastic bottle in small volumes ranging from 50 ml to 2 L. Thus, the self-ignition temperatures of the hydro-alcoholic gels obtained cannot therefore be reached by use or storage in rooms subject to ambient temperature, such as vehicles, except when applying a heat energy source such as a pilot flame [9].
Indeed, the self-ignition process in the hydro-alcoholic gels studied, similar to that of fuels, could be explained by a modification of their chemical kinetics leading to inflammation. Several chemical mechanisms leading to self-ignition have been demonstrated by Corre [26] and Sahetchian et al. [27] allowing in particular to explain the phenomena of cold flames and ignition in one, two or even three stages. Self-ignition is generally described using a chain reaction mechanism with four stages: initiation, propagation, branching and disruption. It is at the level of branching reactions that different chemical mechanisms are considered depending on the temperature at which we are.

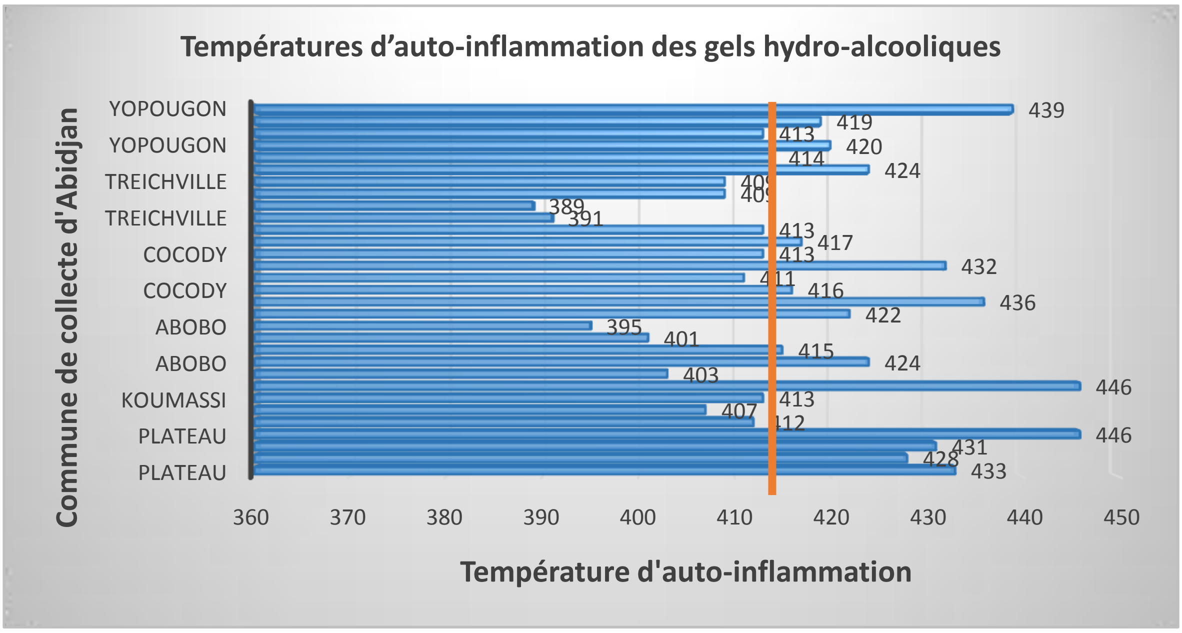

Fig. 3 Self-ignition temperatures of the hydro-alcoholic gels analyzed

CONCLUSION

Few studies have been done on the self-ignition point of hydro-alcoholic gels. The oven method used, based on DIN 51794, provided quantitative information on the self-ignition points of hydro-alcoholic gels currently available in supermarkets in Abidjan. The results of this study clearly reflect the safety data provided in the technical data sheets for the manufacture of hydro-alcoholic gels. The information obtained will be useful to manufacturers, suppliers and traders of these products with regard to the risks, albeit low, of self-ignition in storage areas. However, can't the influence of the physico-chemical parameters of hydro-alcoholic gels explain and help to identify their self-ignition process?

Conflict of Interests
The authors declare that no competing interests exist.

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