



INDIAN KNOWLEDGE SYSTEMS DIVISION

Ministry of Education, Govt of India.

AICTE Headquarters, Nelson Mandela Marg, Vasant Kunj, New Delhi-110070.

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PROJECT COMPLETION REPORT

Important Points:

- i. The Project Completion Report (PCR) should cover the complete work done during the entire project.
- ii. Timely submission of report is essential to facilitate release of funds.
- iii. Report should be in the format given below.
- iv. Write “NIL” against items where there is nothing significant to report or if these items are not relevant.
- v. One soft copy in .pdf format of the report giving information on items listed in the format given below are required. There is no requirement to send a hardcopy.

PROJECT COMPLETION REPORT

PROJECT TITLE

Combustion Experiments to understand the by-products of the Agnihotra Process

SUBMITTED BY

Dr. Nagendra Kumar

(Name of Principal Investigator)

Department of Aerospace Engineering, IIT Bombay, Mumbai 400076

(Name and Address of the Organisation)

(Date of Submission)

FUNDED BY

**Indian Knowledge Systems Division of Ministry of
Education, Govt of India**

IKS Division File Reference No: AICTE/IKS/RFP1/2021-22/13 and
AICTE/IKS/RFP1/2021-22/36

Project Duration: From 2022 to 2024.

PROJECT COMPLETION REPORT

One soft copy of the Project Completion Report should be submitted on email. The Report should consist of Part A - Summary Report and Part B - Comprehensive Report. The report should be on the Standard Format provided.

1. Project Title: Combustion Experiments to Understand the by-products of the Agnihotra Process

2. Duration of Project: From 2022 To 2024

3. Principal Investigator:

Name: Dr. Nagendra Kumar

Organization/Institution: Department of Aerospace Engineering, IIT Bombay, Mumbai

400076

Part A - Summary Report

1. Project Objectives

Objective as per the approved Project	Fully achieved /partially achieved (Indicate shortfall)	Reason for Partial Achievement
Systematically characterize the chemical composition of measurable gaseous byproducts of Agnihotra.	Fully achieved	NA

2. Deliverables

Deliverables as per the approved Project	Fully/Partially/Not Achieved	Reason for Partial/ Non-Achievement
Analysis of the determined weight of Havana Samidhas combusted separately with Mango wood.	Fully achieved	NA
Emission and Temperature Analysis were done at different heights with all the Havana Samidhas combusted together	Fully achieved	NA
Analysis of Havana cones (backflow) with all the Havana Samidhas.	Fully achieved	NA
Analysis of emission and temperature data for Havan Performed by professional pandit with all rituals	Fully achieved	NA

3.Manpower trained

- No. of Students based on the project: 2
- No. of Master's Thesis/Reports based on the project: NA
- Position and Number of Other Technical Staff Trained: NA

4.Methodology (Minimum 250 Words):

4.1) Salient Research Achievements

Summary of Progress against approved work-plan/time schedule of activities planned in the project (Give bulleted list. Indicate percent completed):

The completed work against the approved work plan is tabulated below.

Task	Q1-1	Q1-2	Q2-1	Q2-2	Q3-1	Q3-2	Q4-1	Q4-2
Literature survey and identification of ahutis	100 %							
Small-scale Combustion experiments of individual ingredients		100%						
Small scale combustion of various combination of			100%					
Largescale combustion						100%		
Final Report/Presentation								100%

4.2) New Observations (minimum 200 words):

The experiments were carried out to understand the chemical composition of each ingredient. The carbon and hydrogen fractions in different types of Ghee were found to be around 705% and 11%, respectively. The thermogravimetric analysis of ghee samples showed similar trends for all the different ghee samples. The exothermic peak was observed around 380 °C. The gas chromatography and mass spectroscopy revealed the main compound and its structure present in the ghee samples. Five different compounds were identified to be present in the samples. The carbon fraction in most of the sammidhas was found to be nearly 40%, while the hydrogen fraction was observed to vary from 5-10% in different sammidhas. The two exothermic processes around 350 °C and 460 °C were observed for mango wood and dried cow dung cake, which are the main ingredients used in agnihotra. For completer agnihotra process, the fraction of CO₂, CO was found to be 2.18% and 1244.1 ppm which was measured 150 mm above the agnihotra flame.

4.3) Innovations:

- The experimental setup to study of open wire was designed and fabricated

- The thermal decomposition of Ghee and various ingredients were studied.
- The emissions during the burning of various ingredients were quantified
- The instruments used in Aerospace applications were used for the analysis

5. Indication of scope for future work (Maximum 300 Words):

Future work could include the collection of agnihotra gases and testing them for their medicinal, cleansing properties of the environment.

6. Procurement/Usage of Equipment:

Sr.	Name of Equipment	Make/ Model	Cost (Rs.)	Date of Purchase & Installation	Remarks regarding maintenance/ breakdown
1	Portable 4 gas analyzer	ACE gas analyzer	200600		Working
2	HTC IRX-69 Digita Infrared Thermometer		23,900		Working
3	Power PYE electronics ABS 3 in 1		16,990		Working
4	Intel core i5, 6 C/12 T	Dell	54398		Working
5	Towing Equipement	Local	23,000		Working
6	Unik 5000 series pressure transducer	GE	74,458		Working

Part B – Comprehensive Report

(The Comprehensive Report should be precise in detail and self-contained)

1. Project Title

Combustion Experiments to Understand the by-products of the Agnihotra Process.

2. Literature Review

Various researchers have qualitatively explained the importance of the agnihotra process. Some have also indicated the various compounds that formed in the gas phase during the agnihotra process based on theoretical understanding. A brief review of the literature pertaining to agnihotra process is discussed below.

Acharya [1] provided a brief account of the Yagna. The scientific foundation for Yagna's principal benefits was reviewed, as are some recent results on its effects on health care and environmental purification. The medical applications and psychological and spiritual benefits were also briefly mentioned. Pandya [2] introduced ancient knowledge and modern research findings on Yagna with a focus on preventive and therapeutic applications for holistic healthcare. He provided information on the procedure of Yagna for specific health benefits and the preparation of plant medicinal powders. Findings of recent scientific research on chemical and pharmacological aspects of yagna, its scope in psychological strengthening, and its impact on air pollution were outlined. Brief guidelines on the common type of yagna suitable for everyone and experiments on which can be and should be done were explained in detail.

Satyaprakash [3] signifies the various aspects of Agnihotra, the dimensions of the yagna kunda utilized, the time, place, utensils, offerings, and the process considered for Agnihotra. It mentions the analysis of the fumigating substances such as different kinds of woods, grains, cereals, volatile substances, odoriferous herbs etc. The nature of products of combustion, temperature variations, composition of the fumigants, and photochemical processes were highlighted.

Chaganti [4] discussed the structure and shape of the combustion chamber (Agni kunda) for combustion of ghee, scented materials, herbs, etc. With a specific relation between height, opening, and base, it is found that an inverted truncated pyramid is more efficient, fewer losses, and is cost-effective.

Sharma et al. [5] explained the importance of Agnihotra and how it purifies not only our atmosphere, where we breathe, but also our soul, mind, and body. Innovative ideas were used to reduce the concentration of criteria pollutants using Agnihotra. In this experimental work, a good level of treatment was achieved. Different methodologies were studied using almost 324 Ahuties yagya with cow's desi ghee, Pipal wood (*Ficus religiosa*), Havan samagri. It was concluded that air pollution was reduced by almost 50% - 60% more by yagya when compared to those without yagya. Salem and Böhm [6] reported that wood contains and emits volatile organic compounds, including formaldehyde. Wood emission increases when processing the wood. Formaldehyde is emitted from wood under high heat and can also be detected even if the wood is not heated nearly in ambient conditions. Emission levels depend on Moisture content, temperature, storage time, etc. This mentions the test methods for formaldehyde emissions.

Kjällstrand [7] analyzed the compounds emitted from the wood smoke. Smoke samples were collected using a gas syringe from wood burning under different but more or less choked conditions. Gas chromatography and mass spectrometry were conducted for the collected samples.

Sundin and Roffael [8] used the Flask Method to analyze the amount of HCNO emitted from particle boards and other wood-based panels. This approach also detects the release of HCNO from other materials such as wallpaper, volatile acids, and free phenols from wood-based products, therefore expanding its scope and field of application.

References:

- [1] Acharya, S. S. (2001). The integrated science of yagna. *Shantikunj*, 1, 16-17.
- [2] Pandya, P. (2011). Applied science of yagya for health and environment. *Revised edition. Shantikunj, Haridwar, Uttarakhand, India: Shri Vedmata Gayatri Trust (TMD)*.
- [3] Satyaprakash (2014). Chemistry in Agnihotra, KVRP Publications.
- [4] Chaganti, V.R. (2020). Optimal Combustion Chamber for Yajna/Agnihotri, *Int J Mod Eng Res*, 10, 7-12.
- [5] Sharma, P. K., Ayub, S., Tripathi, C. N., Ajnavi, S., & Dubey, S. K. (2014). AGNIHOTRA—A non conventional solution to air pollution. *Int J Innov Res Sci Eng*, 2, 2347-3207.
- [6] Salem, M. Z., & Böhm, M. (2013). Understanding of Formaldehyde Emissions from Solid Wood: An Overview. *BioResources*, 8(3).
- [7] Kjällstrand, J., Ramnäs, O., & Petersson, G. (1998). Gas chromatographic and mass spectrometric analysis of 36 lignin-related methoxyphenols from

uncontrolled combustion of wood. *Journal of Chromatography A*, 824(2), 205-210.

- [8] Sundin, B., & Roffael, E. (1992). Determination of emissions from wood-based panels using the flask method.

3. Methodology Adopted for Development of the Product/Process in the Research Project

In order to systematically study the agnihotra process, the approach was divided into the following three categories.

1. Characterization of each ingredient: Ghee, wood, etc.
 - a. Using TG/DSC analysis, CHN analysis
 - b. Four different samples of ghee were tested to characterize the ghee as it is the primary ingredient in the agnihotra process.



Fig. 1 Various ingredients used

In the first category, the characterization of each ingredient was carried out. Figure 1 shows the various ingredients used in the present study. The list of all the ingredients is provided later. The characterization was carried out by performing the CHN analysis and thermogravimetric (TG) and differential scanning calorimetry (DSC) analysis. The CHN analysis would provide the fraction of carbon, hydrogen, and nitrogen present in each ingredient. Nitrogen is generally considered as an inert compound as the adiabatic flame temperature in the agnihotra process is not very high. The carbon and hydrogen present in the ingredient would participate in the combustion. Thus, the combustion products of agnihotra would predominantly consist of compounds of carbon and hydrogen. The TG/DSC analysis would help in identifying the extent of the endothermic and exothermic nature of each ingredient.

2. Combustion of ingredients – individual and Combination:

The second step, after characterizing the ingredient, is to understand the combustion behavior of each ingredient. The combustion of each ingredient was carried out in a mix of ghee, which is used as the primary ingredient to enhance the agnihotra process. Gas chromatography (GC) and mass spectroscopy (MS) were performed to determine the combustion products of individual ingredients in the presence of ghee. Figure 2 shows the open fire setup used to characterize the burning of each ingredient. The burning characteristics for a combination of the ingredients are shown in Figs. 2 (b) and 2(c). Figure 3 shows the gas analyzer used for the measurement of the combustion products.

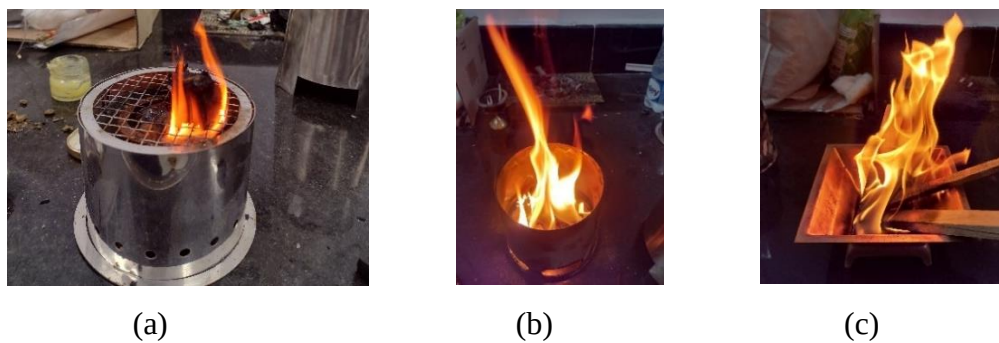


Fig. 2 Individual and mixed burning of ingredients



Fig. 3 Gas analyzer used for emission measurement.

The experimental methodology flow chart is shown in Fig. 4. The weight of each ingredients added during individual burning and burning with Ghee was recorded for each experiment. The in-situ measurements of combustion productions were carried out using the gas analyzer. The open flame and directed flame tests were carried out to determine the gas composition. The directed smoke/flame experimental setup is shown in Fig. 5.

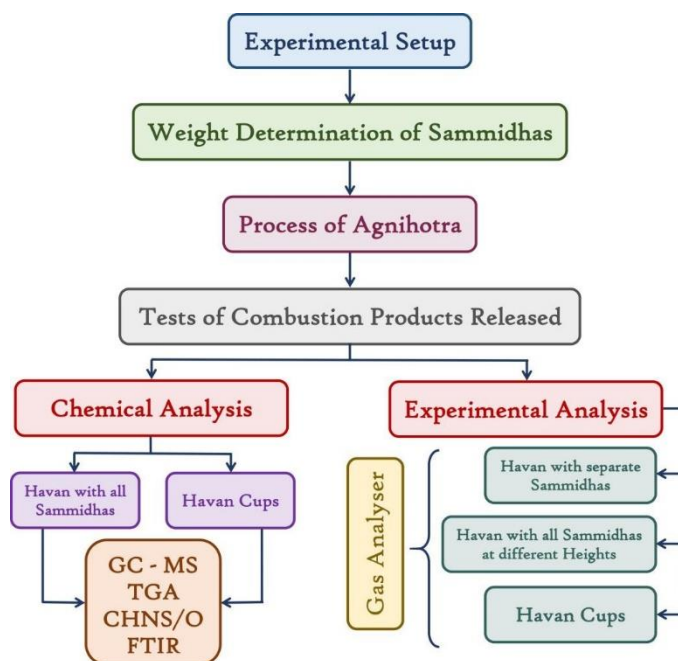


Fig. 4 Flowchart of Experimental Methodology

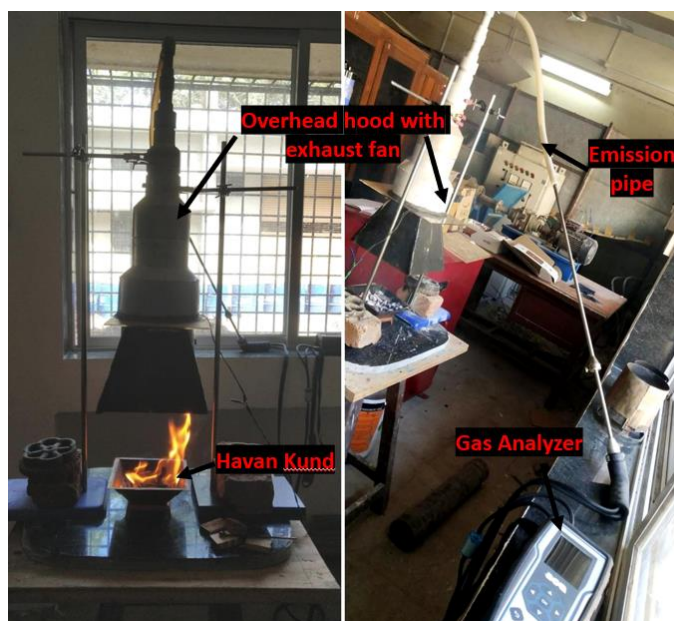


Fig. 5 Experimental setup of Agnihotra overhead exhaust hood

An exhaust overhead hood was used to channel the emitted gas in order to get accurate emission data. Four experimental methods were adopted: first, by analyzing the weight of Havana Samidhas when burned alone with Mango wood; second, by studying Havana at various heights while burning all the Havana Samidhas, noting the weight of each Sammidhas; third, by examining Havana Cones (backflow) using all the Havana Samidhas; and the fourth method involved a professional pandit

performing the Havana with all the rituals.

3. Complete Havan Analysis:

The complete Havan will be carried out as the final step with all the ingredients to characterize and determine the combustion products.

4. Outputs & Outcomes:

a. Technology Development

- Technology developed at Lab scale/pilot scale/commercial scale:
- Technology demonstration in field setup - Yes
- Technology Transfer to industry: NA
- Buyers/End users of product:
- Affordability: NA

b. Knowledge Creation

- Research papers/publications/posters: Under preparation
- Patent filings: Nil
- Participation in conference/ training workshops attended: Nil

c. Knowledge Dissemination

- Describe the strategies used to disseminate the research findings and knowledge.
- Examples of dissemination methods:
 - i. Peer-reviewed publications
 - ii. Conference presentations
 - iii. Workshops and training sessions
 - iv. Online resources (websites, open access repositories)
 - v. Social media outreach

d. Describe how the project How the project resulted in integration of IKS and Contemporary knowledge

e. Knowledge Repository

- Describe the structure and organization of the knowledge repository
- Explain how users/public can access and utilize the knowledge repository.

f. Capacity building

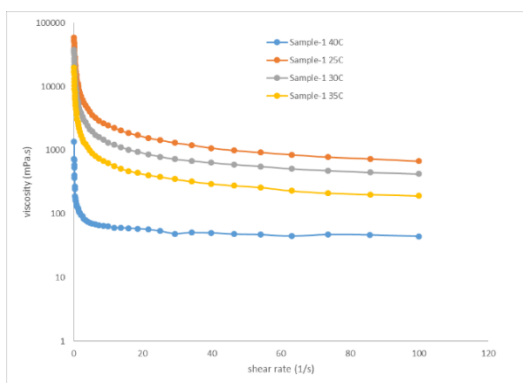
- Officers/faculty: None
- Temporary manpower recruited/trained: 2 students and 1 research intern

g. Results & Analysis with figures

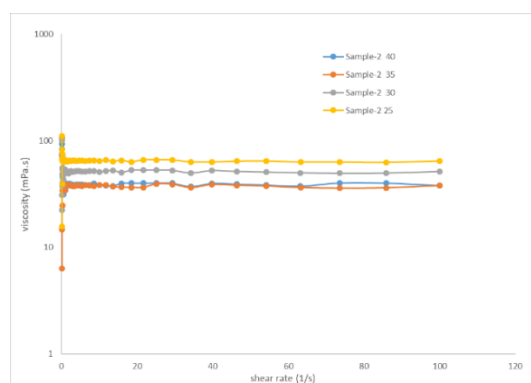
Various scientific analyses were carried out on Ghee and are presented below.

Variation of viscosity of Ghee Samples:

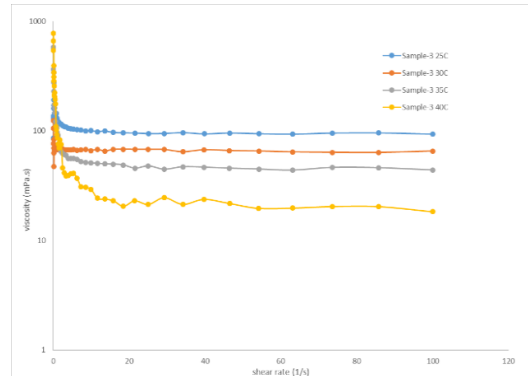
Ghee-1



Ghee-2



Ghee-3



Ghee-4

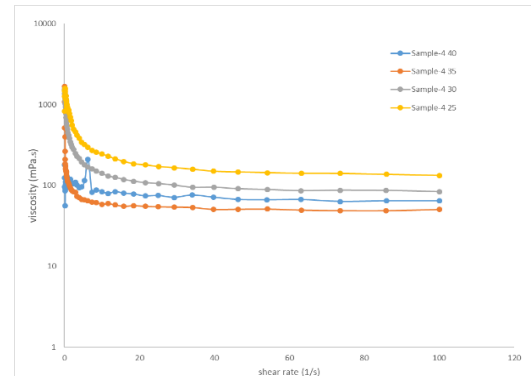


Fig. 6 Viscosity analysis of Ghee

The viscosity varies across the Ghee. However, the viscosity was found to be constant at a higher shear rate. The Ghee behaves as visco-elastic material at starting, however, for a higher shear rate, it does not exhibit a change in viscosity.

CHNS analysis of Ghee samples:

The fraction of carbon, hydrogen, and nitrogen present in various types of Ghee is

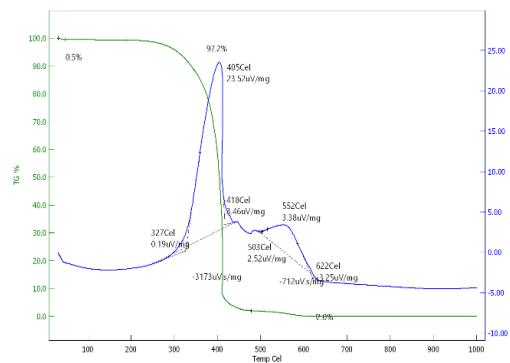
tabulated in Table 2. The nitrogen, carbon, and hydrogen contents vary across the ghee types.

Table 2: CHN analysis of ghee

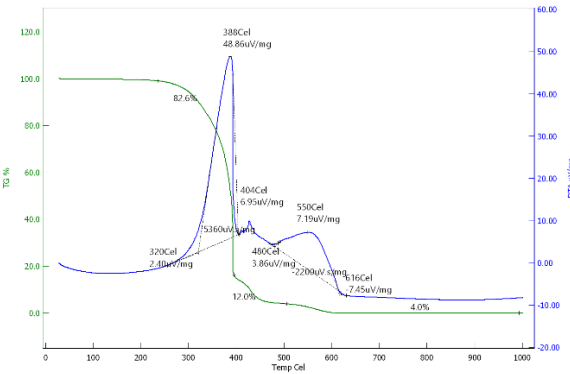
	Nitrogen	Carbon	Hydrogen
Ghee-1	1.045	72.982	11.614
Ghee-2	0.839	69.269	10.997
Ghee-3	0.159	75.066	11.836
Ghee-4	0.157	75.056	12.033

TG/DSC analysis of Ghee:

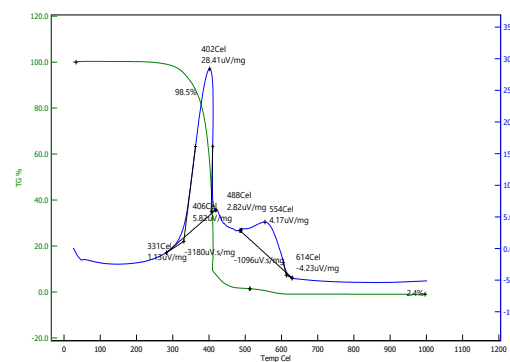
Ghee-1



Ghee-2



Ghee-3



Ghee-4

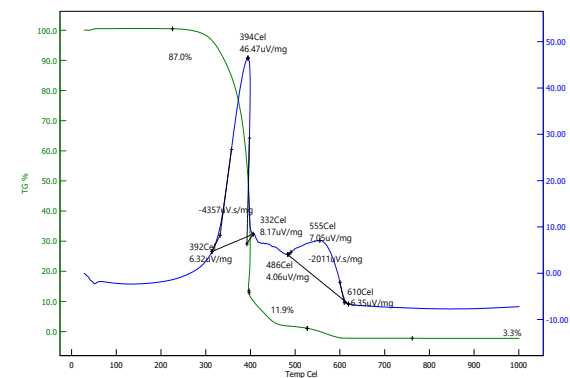


Fig. 7 TG/DSC analysis of Ghee

The Thermo-gravimetric (TG) and Differential Scanning Calorimetry (DSC) analysis of the four types of ghee is shown in Fig. 7. It can be seen from Fig. 7 that the mass loss for all the ghee samples starts around 300 °C. The thermal decomposition will have an initial exothermic peak, which starts around 380 °C for all the ghee samples. It is evident from Fig. 7 that the thermal decomposition of all the ghee samples is similar.

GC- MS analysis data of ghee sample

Gas Chromatography and mass spectroscopy (GC-MS) were performed for all ghee samples. A typical graph obtained in GC-MS analysis is shown in Fig. 8.

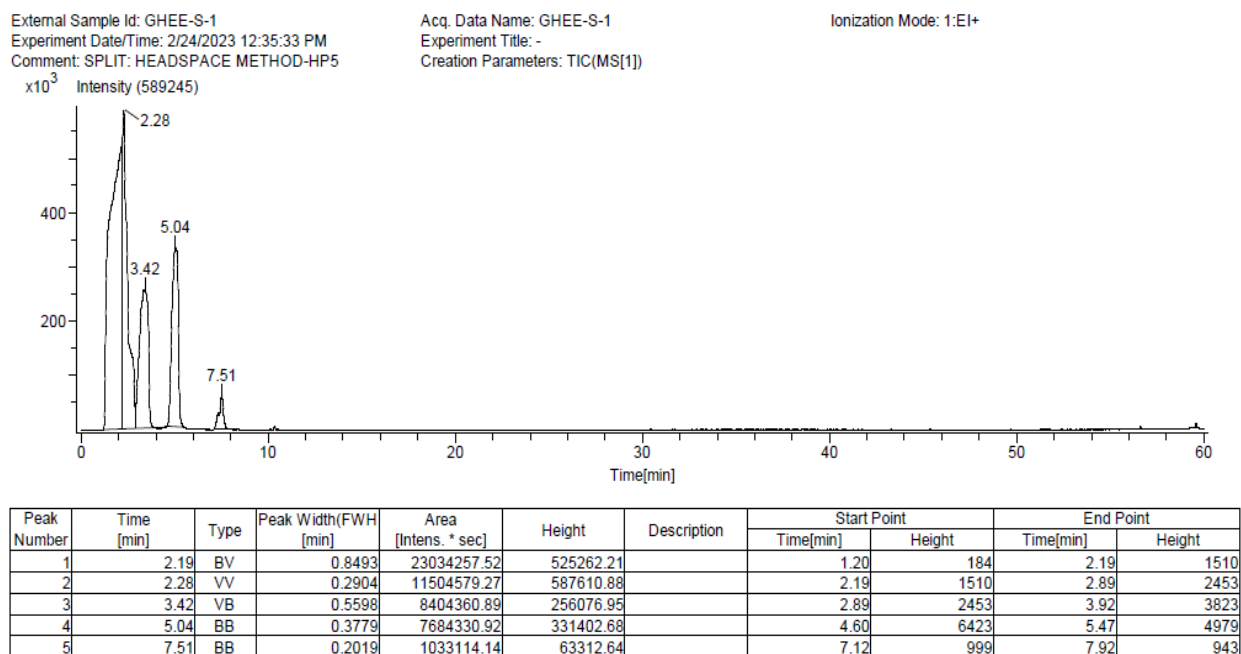
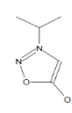


Fig. 8 GC-MS peak analysis

The compounds identified during the analysis are tabulated in Table 3.

Table 3 Compound obtained from GC-MS

Peak No.	Time (min)	Sample detected and chemical formula	Mol. Wt (g/mol)	% contribution	Structure
Peak 1	2.19	Oxetane, 2,2-dimethyl $C_5H_{10}O$	86	71.26	
Peak 2	2.28	4,4-Dimethylazetidin-2-one C_5H_9NO	99	13.61	
Peak 3	3.42	Butane, 2,2-dimethyl- C_6H_{14}	86	8.35	
Peak 4	5.04	Hydroxylamine, O-(2-methylpropyl)- $C_4H_{11}NO$	89	6.67	

Peak 5	7.51	Sydnone, 3-(1-methylethyl)- C ₅ H ₈ N ₂ O ₂	128	0.0916	
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Carbon/Hydrogen/Nitrogen/Oxygen Analysis of various Sammidhas:

The CHNO analysis to identify the fraction of carbon, nitrogen, oxygen, and hydrogen was carried out. Table 4 shows the results obtained for various ingredients. Table 5 shows the average composition of different samples.

Table 4 CHNO analysis of various ingredients

	Nitrogen	Carbon	Hydrogen		Ingredient
Sample_1	0.949	40.016	6.101	ark	
Sample_2	0.961	43.473	6.48		
Sample_3	1.152	41.156	6.066		
Sample_4	0.672	44.051	5.956	palash	
Sample_5	1.324	36.765	4.777		
Sample_6	1.157	41.436	5.153		
Sample_7	1.347	38.14	5.5	audambar	
Sample_8	0.793	42.785	5.848		
Sample_9	1.122	43.205	5.834		
Sample_10	2.346	37.46	5.823	kamal	
Sample_11	2.412	37.659	5.157		
Sample_12	2.684	39.243	5.792		
Sample_13	1.713	40.432	5.716	cow dung	
Sample_14	1.396	39.569	5.531		
Sample_15	1.775	40.103	5.739		
Sample_16	0.679	42.667	6.374	vetiver	
Sample_17	0.682	46.988	6.163		
Sample_18	0.864	78.145	11.638	natural campher	
Sample_19	0.864	78.088	12.43		
Sample_20	0.541	41.335	6.339	cotton	
Sample_21	0.55	41.431	6.262		
ghee					
sample_1	1.045	72.982	11.614		
sample_2	0.839	69.269	10.997		
sample_3	0.159	75.066	11.836		
sampl3_4	0.157	75.056	12.033		

Table 5 Average composition of the ingredients

Samidhas	C (%)	H₂ (%)	N₂ (%)	O₂ (%)
Mango	46.189	6.008	0.322	30.054
Ark	43.110	5.486	0.349	
Palasha	42.110	5.698	0.429	29.562
Khadir	43.911	5.881	0.432	31.707
Ashwatha	45.134	6.266	0.449	29.016
Audumbara	43.363	5.800	0.920	29.028
Shami	44.108	5.828	0.280	33.978
Kusha	41.915	5.938	0.538	33.599
Cowdung	40.092	5.492	1.394	28.504
Havana Samagri	42.891	5.565	1.002	29.509
Ric Grain	40.060	6.766	1.425	38.387

TG/DSC analysis of Mango wood and Dried Cow Dung cake

The mass loss of the mango wood and dried cow dung cake was studied. The mass loss studies result in the understanding of the decomposition and further pyrolysis extent of the ingredient. The DSC analysis of the mango wood and dried cow dung cake was carried out to determine the endothermic and exothermic peaks. The corresponding temperature of the peaks was also studied.

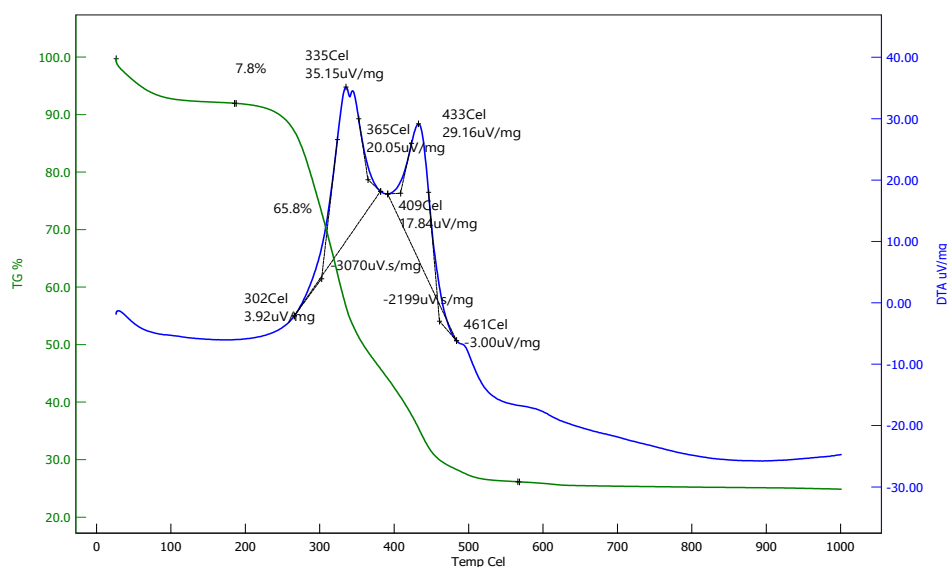


Fig. 9 TG/DSC analysis of mango wood

It can be seen from Fig. 9 that the mango wood has two slope decomposition in terms

of mass loss. The initial mass loss starts at 30-40 °C, and it remains almost constant till 250 °C. The rapid mass loss is observed from 250 °C to 450 °C. Around 8% of the mass is lost during the initial phase, while 66% of the mass is decomposed during the second phase. A residue of 25% was observed. The initial mass loss is primarily due to the endothermic decomposition of the mango wood. The exothermic peak is observed around 350 °C, where the rapid mass loss of the mango wood is observed. There is a second exothermic peak around 450 °C, which marks the complete decomposition of the mango wood.

Figure 10 shows the TG/DSC analysis of dried cow dung cake. It can be seen from Fig. 10 that around 7% mass loss occur during the endothermic decomposition while

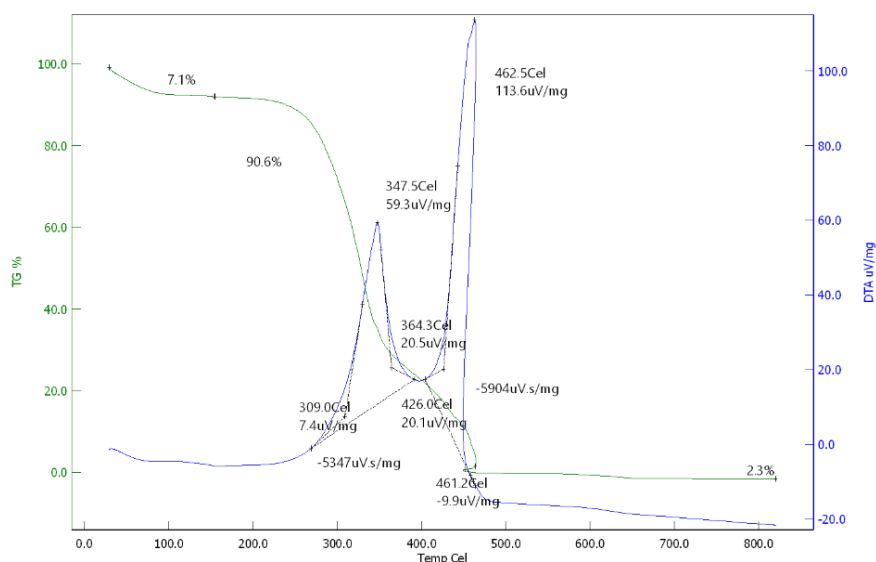


Fig. 10 TG/DSC analysis of dried cow dung cake

90% mass loss was observed during the exothermic decomposition. A residue of 2-3% was observed during the TG analysis. The exothermic decomposition starts at 300 °C and the first exothermic peak was observed at 350 °C. The second exothermic peak was observed around 450 °C.

Combustion Products analysis:

The combustion analysis of individual ingredients and the combination of ingredients with ghee is presented in Fig. 11. The emissions of each samidhas were observed using a Gas Analyzer when burnt with the base wood of Mango. The weight of each samidha was between 10 - 15 grams, along with the Mango wood of 30 - 40 grams. It can be seen from Fig. 11 that formation of carbon monoxide and partially burnt hydrocarbons are

formed. There is a small fraction of Sulphur dioxide is also released during the burning. The formation of CO is primarily due to insufficient oxygen as the composition becomes highly fuel-rich. The same is the reason for the formation of partially burned hydrocarbons.

	Nitrogen	Carbon	Hydrogen	Ingredient
Sample_1	0.949	40.016	6.101	ark
Sample_2	0.961	43.473	6.48	
Sample_3	1.152	41.156	6.066	
Sample_4	0.672	44.051	5.956	palash
Sample_5	1.324	36.765	4.777	
Sample_6	1.157	41.436	5.153	
Sample_7	1.347	38.14	5.5	audambar
Sample_8	0.793	42.785	5.848	
Sample_9	1.122	43.205	5.834	
Sample_10	2.346	37.46	5.823	kamal
Sample_11	2.412	37.659	5.157	
Sample_12	2.684	39.243	5.792	
Sample_13	1.713	40.432	5.716	cow dung
Sample_14	1.396	39.569	5.531	
Sample_15	1.775	40.103	5.739	
Sample_16	0.679	42.667	6.374	vetiver
Sample_17	0.682	46.988	6.163	
Sample_18	0.864	78.145	11.638	natural campher

Sample_1 9	0.864	78.088	12.43	
Sample_2 0	0.541	41.335	6.339	cotton
Sample_2 1	0.55	41.431	6.262	
ghee				
sample_1	1.045	72.982	11.614	
sample_2	0.839	69.269	10.997	
sample_3	0.159	75.066	11.836	
sampl3_4	0.157	75.056	12.033	

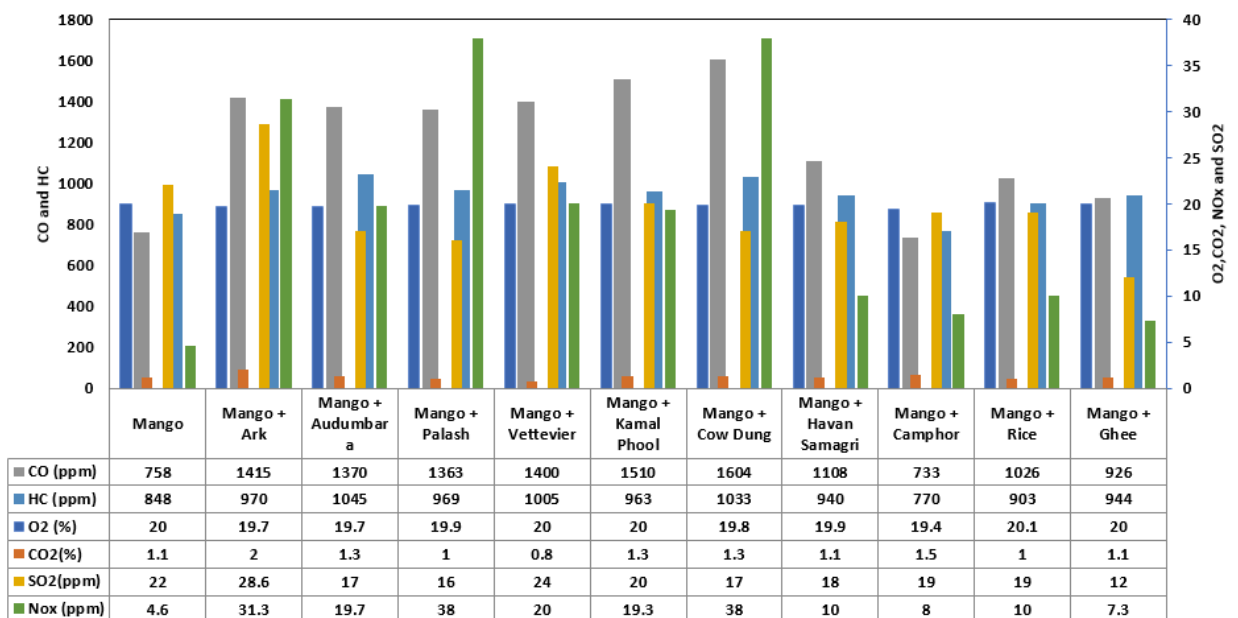


Fig. 11 Emission graph of each ingredient

Samidhas in Table 6 includes Ark, Palash, Khadir, Ashwatha, Audumbara, Shami, Havana Samagri, Rice grains each weighing 5 grams, Mango wood of 150 grams, Camphor of 2.5 grams, Cow dung of 12 grams, Kusha of 1.5 - 2 grams and Ghee of 30 - 40 grams. The Emissions produced were analyzed using a Gas analyzer and a Thermocouple placed at different heights.

Table 6 Analysis of Havan at different heights

Height	O ₂	CO ₂	CO	SO ₂	HC	NO _x	ST	TC
(inches)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(°C)	(°C)

6	18.57	2.18	1244.1	75.17	709.28	13.38	257.95	650 - 850
12	18.69	2.21	976.52	86.98	584.50	24.61	267.5	200 - 350
18	19.87	0.99	231.34	29.19	341.97	8.24	171.56	150 - 200

Analysis of Havana cones (back flow) with all the Havana Samidhas.

Here, the Samidhas include Ark, Palash, Khadir, Ashwatha, Audumbara, Shami, Havana Samagri, Rice grains each weighing 5 grams, Mango wood of 40 grams, Camphor of 2.5 grams, Cow dung of 12 grams, Kusha of 1.5 - 2 grams which were powdered in course manner and mixed using ghee of 30 - 40 grams and distilled water. A Cone of 8 grams was formed and burnt to analyze. The Emissions produced were analyzed using a gas analyzer and thermocouple at the top and bottom positions, as indicated in Table 7.

Table 7: Analysis of Havan Cones

Position	O₂ (%)	CO₂ (%)	CO (ppm)	SO₂ (ppm)	HC (ppm)	NO_x (ppm)	ST (°C)	Thermocouple (°C)
Top	20.87	0.0323	391.66	15.19	610.97	0.067	48.68	90 - 130
Bottom	20.89	0.0016	207.9	13.0	442.40	0.0025	41.18	38 - 45

Analysis of emission and temperature data for Havan Performed by professional pandit with all rituals

Pandit performed Gan havan and explained the importance of performing havan and its scientific touch

Purpose of the Gan Havan

- Seeking blessings of Lord Ganpati for various aspects of life.
- Purification of the surroundings and participants.
- Spiritual progress and overall well-being of the community.



Fig. 12 Gan havan performed by Pandit ji

Ingredients Used and their importance:

- **Mango wood:** Symbolic of purity and auspiciousness.
- **Ark wood:** Considered sacred and used in religious rituals.
- **Palash sticks:** Representing the Flame of the Forest, used in worship.
- **Audumbara sticks:** Believed to have spiritual significance.
- **Kamal phool (Lotus flower):** Considered auspicious and a symbol of purity.
- **Vetiver dry shrub:** Utilized for its aromatic properties.
- **Cow dung cake:** Traditional fuel symbolizing purity and prosperity.
- **Rice grains:** Offered as a symbol of abundance and prosperity.
- **Camphor:** Used for its purifying properties.
- **Ghee:** Clarified butter, a common offering in Yajnas.
- **Mahaprashad:** A sacred mixture of pocha, jaggery, sesame seeds, and sugar.
- **Havan Samagri:** A mixture of various sacred herbs and other substances used in the Havan fire for invoking divine energies.

Procedure, Symbolism and Outcome:

- Panditji followed a precise ritualistic procedure, making offerings into the consecrated fire.

- Chanting of specific Ganpati mantras accompanies each offering.
- The fire is considered a medium to convey the offerings to the divine.
- Each ingredient holds symbolic significance, invoking specific aspects of Lord Ganpati's blessings.
- The Havan represents a sacred communion between the divine and the devotees.
- The collective prayers and offerings are believed to bring about positive energies, blessings, and spiritual progress for the community and individuals.

Experimental procedure and results

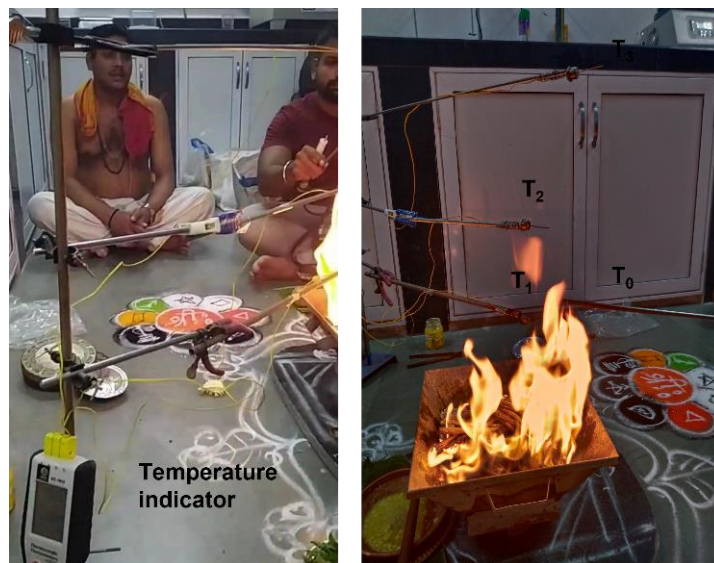


Fig.13 Thermocouple and Temperature Indicator

1. **Initiation of Havan Fire:**
 - Mango wood, coconut shell, coconut oil, and camphor are included in the commencement of the Havan fire.
2. **Ghee Offering:**
 - Ghee offering follows, sustaining a continuous and vibrant flame, releasing a pleasant aroma when heated.
3. **Mahaprashad Offering:**
 - Mahaprashad includes poha, jaggery, sesame seeds, sugar, coconut oil, and sugar.

- Symbolizes the five elements (earth, water, fire, air, and ether) in a harmonious union during the ritual.
4. **Durva Grass in Ganpati Pooja:**
 - Durva grass is used in Ganpati Pooja for good luck and positive energy.
 - The three blades symbolize the trinity of Brahma, Vishnu, and Mahesh (Shiva).
 5. **Bioactive Compounds in Ritual Elements:**
 - Palash wood, Ark wood, Vetteiver dry shrub, Kamal phool contain bioactive compounds with antimicrobial and insecticidal properties.
 - Smoke generated during Havan may possess antimicrobial properties due to burning specific plant materials.
 6. **Offered Samigri Ingredients:**
 - Bhimseni kapoor, rose petals, sandalwood powder, lobaan, ghee, chandan, Nagkesar, Tagar, Agar, wala, Red Sandal powder, Nagarmotha, Lotus seeds, Jata masi, Batriso Dhoop, Kapoor Kachri, Satavari, Turmeric.
 7. **Traditionally Used Dung Cake:**
 - Dung cake is traditionally used as fuel due to its easy availability.
 - Smoke generated during burning may have antimicrobial properties.
 - It is a sustainable practice involving the recycling of natural waste for a practical purpose.
 8. **Characteristics of Dung Cake:**
 - Dung cake takes time to ignite.
 - It creates a substantial amount of smoke during burning.
 9. **Conclusion of Havan:**
 - Havan concludes by adding all remaining ingredients with a large quantity of ghee to the burning fire.

The emission data recorded during the complete Havan is presented in Fig. 14. The emissions were collected while adding each ingredient. The emissions were found to consist of partially burnt hydrocarbons, carbon monoxide, carbon dioxide, and a small quantity of sulfur dioxide. The formation of a few nitrogen oxides was also observed.

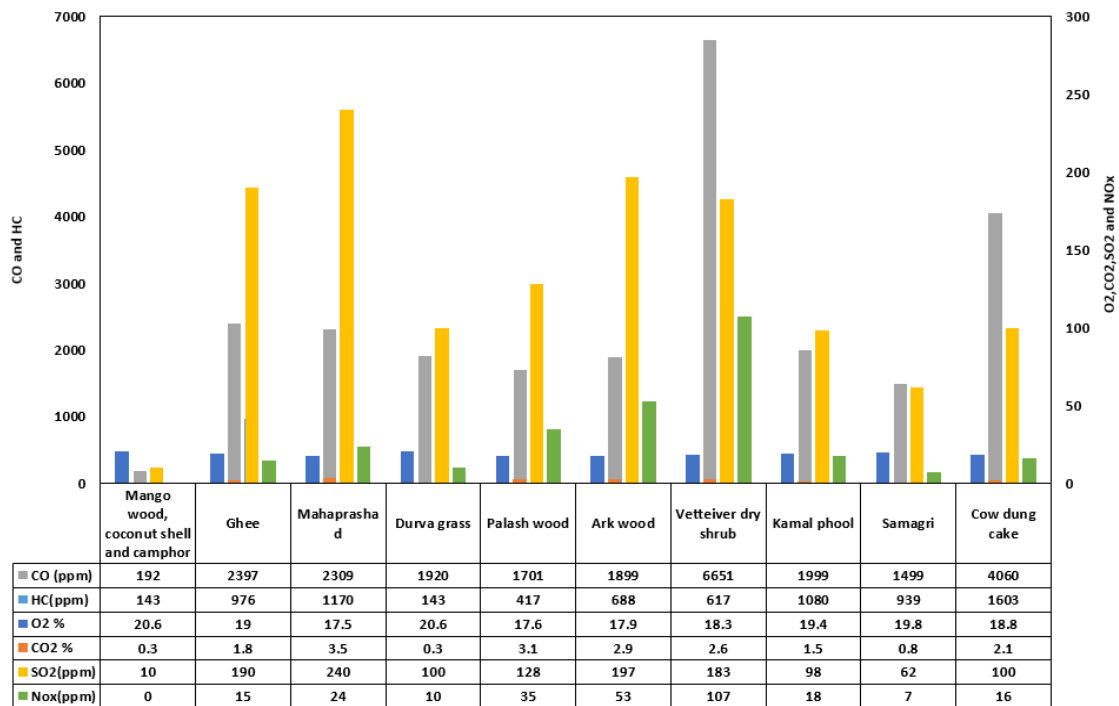


Fig. 14 Emission graph of complete Havan

Temperature data

- Using K-type thermocouples (T1, T2, and T3) are connected to temperature indicator and fixed at specific heights of 0, 5, 10, 15, 20 inches named T0, T1, T2, and T3 were shown in Fig. 13, while NI DAQ monitored varying temperatures by positioning T0 thermocouple.
- The room temperature increased from 26°C before the Havan to 35°C during the Havan ceremony.

Table 9 Temperature results of Gan Havan measured surface to a maximum height of the flame.

Height from surface (cm)	Temperature (°C)
Surface	900-1000
5	680-750
15	380-450
30	200-320
45	80-180

Effect on Flue gas analyzer sensor and filter life

- Upon analyzing the sensor lifespans, it was observed that there is a decline in longevity ranging from 60% to 70% across all sensors.

- The attached filter on the flue gas analyzer, as depicted in the figure, illustrates the difference between a used and unused filter.
- The used filter incurred damage due to the accumulation of trapped particulate matter

h. Achievements/ highlights of the project

- A novel experimental setup to determine the combustion products has been designed and fabricated.
- The composition of the ingredients used in the Agnohotra was determined.
- The characterization of different types of ghee was carried out.
- The characterization of mango wood and cow dung cake was carried out.
- The combustion products due to the burning of individual ingredients and a mix of ingredients were characterized.
- The combustion products of completer Agnihotra were measured.

i. References

- [1] Acharya, S. S. (2001). The integrated science of yagna. *Shantikunj*, 1, 16-17.
- [2] Pandya, P. (2011). Applied science of yagya for health and environment. *Revised edition. Shantikunj, Haridwar, Uttarakhand, India: Shri Vedmata Gayatri Trust (TMD)*.
- [3] Satyaprakash (2014). Chemistry in Agnihotra, KVRP Publications.
- [4] Chaganti, V.R. (2020). Optimal Combustion Chamber for Yajna/Agnihotri, *Int J Mod Eng Res*, 10, 7-12.
- [5] Sharma, P. K., Ayub, S., Tripathi, C. N., Ajnavi, S., & Dubey, S. K. (2014). AGNIHOTRA—A non conventional solution to air pollution. *Int J Innov Res Sci Eng*, 2, 2347-3207.
- [6] Salem, M. Z., & Böhm, M. (2013). Understanding of Formaldehyde Emissions from Solid Wood: An Overview. *BioResources*, 8(3).
- [7] Kjällstrand, J., Ramnäs, O., & Petersson, G. (1998). Gas chromatographic and mass spectrometric analysis of 36 lignin-related methoxyphenols from uncontrolled combustion of wood. *Journal of Chromatography A*, 824(2), 205-210.
- [8] Sundin, B., & Roffael, E. (1992). Determination of emissions from wood-based panels using the flask method.

j. Appendices

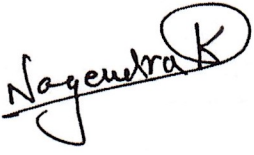
None

k. Project Outcomes Contribution to (Bullet points. No more than 250 words in each category)

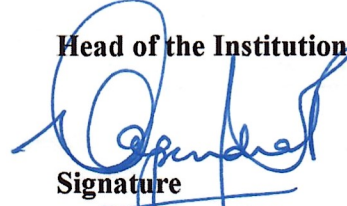
- Drṣṭi:
 - The present study has improved the understanding of the combustion products of Agnihotra.
- Jñāna:
- Laukika-prayojana:

Name of PI:
Dr. Nagendra Kumar

Signature of PI



Head of the Institution



Signature

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