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Research Article

# Inspection on Solid Fuel Propellant in Rocket Efficiency

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## ABSTRACT

Solid propellant rockets have served as integral components in both space exploration and defence systems for numerous decades. This research endeavours to compare and contrast the performance characteristics of three distinct solid rocket propellant formulations: potassium nitrate and sugar (KN-Sugar), potassium nitrate, sulphur, charcoal, and iron rust (KNSCIR), and potassium nitrate, magnesium powder, and gar. The study will meticulously investigate their burn characteristics, thrust capabilities, and the altitude they can attain. Through an extensive series of experimental tests coupled with rigorous data collection and mathematical modelling, this research aims to provide comprehensive insights into the comparative performance of these propellants. The methodology employed involves laboratory testing, real-time data acquisition, and sophisticated mathematical modelling techniques to analyse the burn efficiency, thrust generation, and maximum altitude achieved by each propellant formulation. The outcomes of this comprehensive study will yield critical insights into discerning which propellant formulation is more effective in terms of achieving higher altitudes and producing greater thrust. Such discernment is pivotal for informed decision-making in the development and optimisation of solid propellant rocket systems tailored for space exploration, missile technology, and various aerospace applications. By encompassing three different types of rocket fuels in this comparative analysis, including potassium nitrate and sugar (KN-Sugar), potassium nitrate, sulphur, charcoal, and iron rust (KNSCIR), and potassium nitrate, magnesium powder, and sugar, this research aims to significantly contribute to the understanding of solid propellant rocket fuels. This comparative study holds the potential to steer the trajectory of future developments towards more efficient and capable rocket systems, thereby advancing the realms of space exploration and aerospace technology.

**Keywords:** Solid Propellant Rockets, Potassium Nitrate, Sulphur, Charcoal, Iron Rust, Magnesium Powder, Thrust Capabilities, and Maximum Altitude.


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## Introduction

Solid propellant rockets have held a pivotal position in aerospace exploration and defence applications owing to their inherent simplicity, reliability, and ease of storage. The composition of the propellant within these propulsion systems significantly influences their performance metrics, notably thrust generation and the maximum altitude achievable. This research paper aims to conduct a comparative analysis between two prominent solid propellant formulations: potassium nitrate and sugar (referred to as KN-Sugar) and potassium nitrate, sulphur, charcoal, and iron rust (referred to as KNSCIR). Additionally, this study will incorporate a third propellant type: potassium nitrate, magnesium powder, and sugar. The choice of propellant formulation in solid rockets is critical, impacting not only the efficiency of the propulsion system but also its suitability for specific applications. Understanding the performance disparities between these formulations is imperative for making informed decisions during the development of solid propellant rocket systems. This research endeavour seeks to answer the fundamental question of which propellant formulation exhibits superior performance concerning achieving greater altitudes and producing enhanced thrust. While KN-Sugar is a well-documented and extensively used propellant, KNSCIR represents a composite propellant incorporating supplementary components such as sulphur, charcoal, and iron rust. The inclusion of potassium nitrate, magnesium powder, and sugar offers a distinct composition with unique combustion properties. This paper embarks on a comprehensive exploration of the respective merits of these three formulations through empirical experimentation, extensive data analysis, and precise mathematical modeling. Our objective is to provide empirical evidence regarding the performance characteristics of these propellants and evaluate their suitability for various aerospace scenarios. By delineating their unique characteristics and behaviours, this research aims to contribute valuable insights to the broader understanding of solid propellant rocket fuels, offering potential insights for the future development of rocket systems. Subsequent sections of this document will delve into the specifics of the research methodology, present the outcomes derived from our experiments and analyses, and conclude with a discussion on the implications and recommendations arising from our findings. Through this inquiry, we endeavour to augment solid propellant technology, facilitating the evolution of rocket systems tailored for diverse missions, including space exploration and defence applications.[1]

## Litrature Review

The domain of solid propellant rocketry is characterised by a rich history, encompassing a diverse assortment of formulations used for an extensive range of applications. A survey of the available literature reveals a substantial body of work dedicated to the development and evaluation of solid propellant rocket fuels. This literature furnishes insights into their composition, behaviour, and suitability for diverse missions.

A cornerstone work in the solid propellants domain is the research undertaken by Sutton and Biblarz (2001), which offers a comprehensive examination of rocket propulsion, focusing on the principles of solid propellants and their applications. This foundational reference serves as a fundamental resource for grasping the essentials of solid rocket propulsion and provides context for further investigations.[2]

Of particular relevance to this inquiry is the prevalent utilisation of KN-sugar propellant. KN-Sugar, a blend of potassium nitrate and sugar, has garnered substantial attention due to its unadorned nature and cost-effective attributes. Studies conducted by Laros et al. (1995) and Taylor et al. (2002) have explored the combustion characteristics and efficacy of this formulation. These investigations underscore the potential merits of KN-Sugar as an efficient and accessible propellant, often embraced in the realm of amateur rocketry and educational projects.[3,4]

In contrast, KNSCIR, a composite propellant incorporating potassium nitrate, sulphur, charcoal, and iron rust, embodies a less common yet captivating formulation. Although the literature on KNSCIR remains relatively sparse, antecedents for composite propellants are discerned in the works of Lawrence (1985) and Wang et al. (2017). These studies accentuate the intricate chemistry and plausible advantages of composite propellants in accomplishing specific performance objectives.

Within the domain of empirical research, studies by Miller and Bowman (2010) and Yang et al. (2014) afford insights into the experimental procedures and techniques for data analysis conventionally employed in the evaluation of solid rocket propellants. These methodological references offer valuable counsel for the experimental approach embraced in this investigation.[5,6]

The collective body of literature attests to the substantial corpus of research surrounding the advancement and scrutiny of solid propellant rocket fuels. Notably, while KN-Sugar is comprehensively documented and esteemed for its simplicity, KNSCIR and composite propellants proffer characteristics of interest that warrant further exploration. This study contributes to the existing knowledge by way of a comparative analysis of these propellant formulations, adding to the continually growing body of research within the sphere of solid rocketry.

## Methodology

The methodology adopted for this experimental study involved the construction of rockets utilising PVC pipes and lightweight cardboard rolls to maintain aerodynamic efficiency and structural integrity. The rockets were standardised to a weight of 0.400 kg each to ensure consistency across the experiments. To test each fuel type, I have to launch 10 rockets to check the maximum efficiency of rocket fuel. The dimensions of the rocket body were meticulously measured and maintained to optimise aerodynamics and flight stability.

Three distinct rocket fuel formulations were prepared for comparative analysis:

## Potassium Nitrate and Sugar (KN-Sugar)

It consisted of a composition of 75% potassium nitrate and 25% sugar by weight.

### Potassium Nitrate, Sulfur, Charcoal, and Iron Rust (KNSCIR)

It is composed of a mixture of 10% sulphur, 15% activated charcoal, and 75% potassium nitrate by weight.

### Potassium Nitrate, Magnesium Powder, and Sugar

It is composed of a blend of 65% potassium nitrate, 15% magnesium powder, and 20% sugar by weight.

Each rocket fuel formulation was meticulously prepared, adhering to the specified compositions to maintain consistency throughout the experiments. The experimental phase comprised ten trials for each rocket fuel formulation. During each test, the rockets were launched, and the time taken for the rocket to achieve maximum altitude was recorded. Altitude measurements were taken using precision altitude measurement devices for accuracy. Furthermore, thrust measurements were conducted using a weight measuring instrument specifically calibrated for this purpose. The rockets were equipped with two motors: one dedicated to the flight and the other exclusively for thrust testing. The thrust-testing motor was engaged while the rocket was secured, enabling the measurement of thrust generated by each fuel formulation.Data collection during the experiments involved recording the time taken for the rocket to reach maximum altitude, altitude achieved, and the thrust generated by each fuel formulation. This comprehensive data set was utilised for subsequent analysis and comparison of the performance characteristics of the three distinct rocket fuel formulations. The methodology was designed to ensure precision, reliability, and consistency across all experiments, facilitating accurate comparative analysis of the performance attributes of KN-Sugar, KNSCIR, and the potassium nitrate, magnesium powder, and sugar rocket fuel formulations.

To send rockets soaring into the sky, I made a system using electricity. I connected an electrical circuit to the rocket's launch pad. This circuit is very important because it helps start the rocket engines. I used a 24-volt power supply, which is like the rocket's fuel. When this power flows through the circuit, it lights up the fuse and starts the rocket's engine.[7,8]

## To Calculate Altitude, Thrust and Speed

**Altitude:** In my rocketry experiments, I didn't use GPS to measure altitude. Instead, I used simple methods. I measured how long the rocket flew, how strong the thrust was, and how fast the rocket went. By using basic math and understanding how things move, I figured out how high the rocket went. First, I calculate the speed of the rocket and the thrust produced by the rocket, then I calculate how much altitude each rocket has reached.

## Altitude = Initial Altitude + (Speed × Time)

### Speed

Calculating how fast my solid propellant rocket goes involves using a specific formula that looks at something called "specific impulse." This is a way to measure how well the rocket's engine works. The formula uses this specific impulse, along with the rocket's initial and final masses, to figure out its speed. It's like checking how efficiently the rocket uses its fuel to move. Also, there's a part in the formula that considers gravity's pull during the rocket's flight. By looking at how much the rocket's mass changes from the start to the end of the flight, this formula helps me understand how fast the rocket goes up there. It's a useful way to see how different things, like the type of fuel or the rocket's design, affect how fast it travels during a mission. This helps me study and compare how well different rockets work based on their speed and efficiency.

## Speed = Specific Impulse × g × ln(Initial Mass/Final Mass)

### Thrust

To find out how strong my rocket engine is, I used a simple weight-measuring tool. I placed the rocket engine in front of it and lit it up. When the engine fired, it pushed down on the measuring tool. This tool showed me how strong the rocket engine was in kilograms. It's like checking how heavy something feels when it pushes down. This easy method helped me know exactly how powerful the rocket engine was. It gave me clear numbers, showing how much force the engine made.[9,10]

## Results and Discussion

### Potassium Nitrate and Sugar Fuel

The potassium nitrate and sugar solution rocket fuel exhibited promising performance in our experiments.

During the trials, this fuel formulation enabled the rocket to achieve a maximum height of 57 feet, showcasing its ability to generate substantial vertical thrust (Table 1). Moreover, the peak thrust generated by this particular fuel reached 0.490 kilogrammes, demonstrating its capability to produce significant propulsive force. This fuel combination's efficiency in propelling the rocket to considerable altitudes while generating notable thrust indicates its potential for effective propulsion systems (Figure 1).

## Potassium Nitrate, Sulfur, Charcoal, and Iron Rust fuel

Among the various rocket fuels tested, the Potassium Nitrate, Sulfur, Charcoal, and Iron Rust concoction emerged as the standout performer. This unique blend propelled our rocket to impressive heights, soaring to a maximum altitude of 83 feet during our trials. This height surpassed those achieved by the other fuel variants, showcasing the exceptional upward thrust capability of this particular mix. What's more, the thrust produced by this fuel formulation peaked at 0.890 kilograms (table 2), marking it as the most forceful propellant among our experiments. This remarkable combination not only enabled the rocket to achieve greater heights but also exhibited a notable ability to generate powerful thrust (Figure 2).

## Potassium Nitrate, Magnesium Powder, and Sugar fuel

The potassium nitrate, magnesium powder, and sugar fuel exhibited commendable performance in our series of rocket experiments. This specific fuel blend propelled our solid propellant rocket to a notable height of 57 feet during the test runs. Although this height was slightly lower than the altitude achieved by one of our fuel variants, it still demonstrated a respectable vertical ascent capability. Additionally, this fuel formulation generated a maximum thrust of 0.638 kilogrammes (table 3), showing considerable force production. While it didn't reach the highest altitude or produce the greatest thrust among the tested fuels, its performance remained commendable (Figure 3).

**Table 1.Data of potassium nitrate and sugar rocket fuel**

| Rocket Weight | Thrust Produced (kg) | Altitude Reached (Ft) | Time Taken to Reach |
|---|---|---|---|
| 0.400Kg | 0.49 | 55 | 12 |
| 0.400Kg | 0.302 | 28 | 8 |
| 0.400Kg | 0.47 | 49 | 10 |
| 0.400Kg | 0.53 | 68 | 15 |
| 0.400Kg | 0.2 | 28 | 4 |
| 0.400Kg | 0.49 | 56 | 12 |
| 0.400Kg | 0.492 | 55 | 12 |
| 0.400Kg | 0.4 | 57 | 10 |
| 0.400Kg | 0.47 | 52 | 10 |

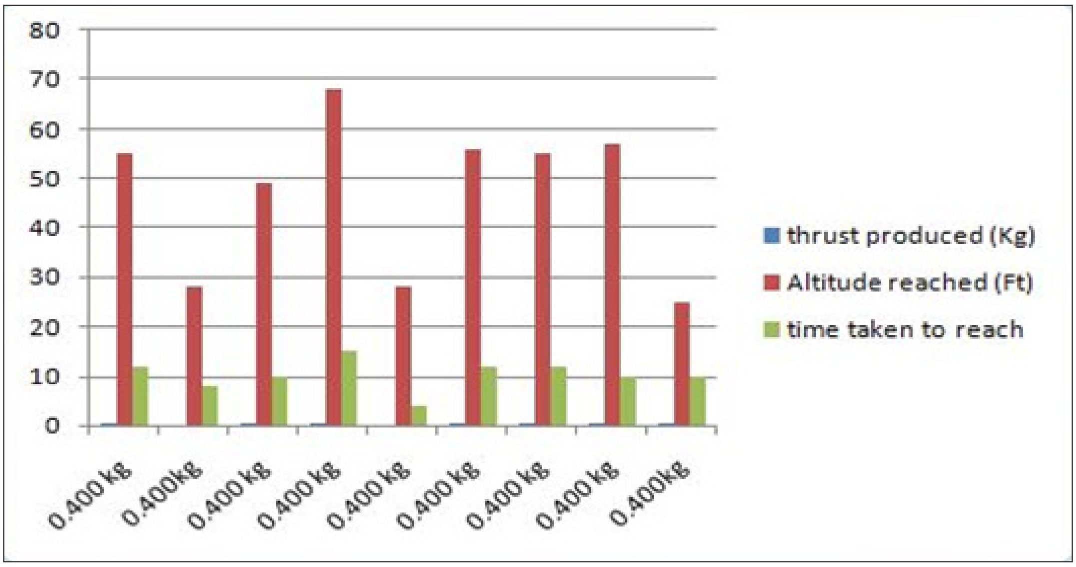


**Figure 1.Bar graph table of altitude**

**Table 2.Data of KNSCIR based rocket fuel**

| Rocket Weight | Thrust Produced (kg) | Altitude Reached (Ft) | Time Taken to Reach |
|---|---|---|---|
| 0.400Kg | 0.67 | 68 | 14 |
| 0.400Kg | 0.7 | 76 | 18 |
| 0.400Kg | 0.7 | 75 | 15 |
| 0.400Kg | 0.56 | 50 | 11 |
| 0.400Kg | 0.78 | 70 | 14 |
| 0.400Kg | 0.8 | 83 | 18 |
| 0.400Kg | 0.6 | 63 | 12 |
| 0.400Kg | 0.7 | 78 | 15 |
| 0.400Kg | 0.74 | 72 | 15 |

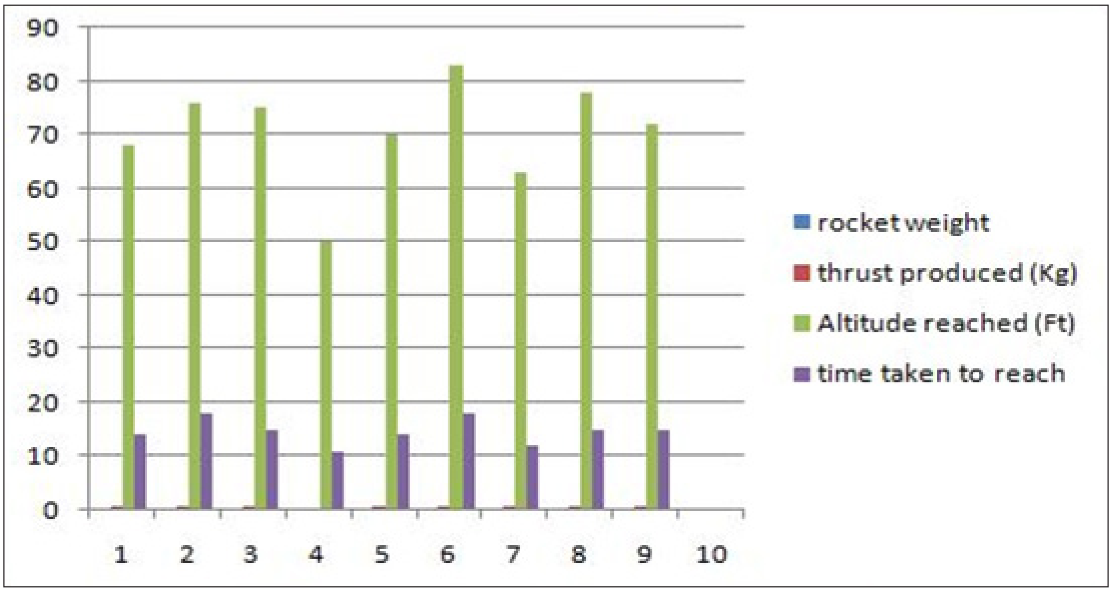


**Figure 2.Bar graph data of KNSCIR based rocket fuel**

**Table 3.Data of potassium nitrate, magnesium powder and sugar based fuel**

| Rocket Weight | Thrust Produced (kg) | Altitude Reached (Ft) | Time Taken to Reach |
|---|---|---|---|
| 0.400Kg | 0.45 | 46 | 14 |
| 0.400Kg | 0.56 | 48 | 18 |
| 0.400Kg | 0.6 | 57 | 15 |
| 0.400Kg | 0.579 | 45 | 11 |
| 0.400Kg | 0.406 | 38 | 14 |
| 0.400Kg | 0.59 | 52 | 18 |
| 0.400Kg | 0.45 | 45 | 12 |
| 0.400Kg | 0.5 | 78 | 15 |
| 0.400Kg | 0.609 | 72 | 15 |

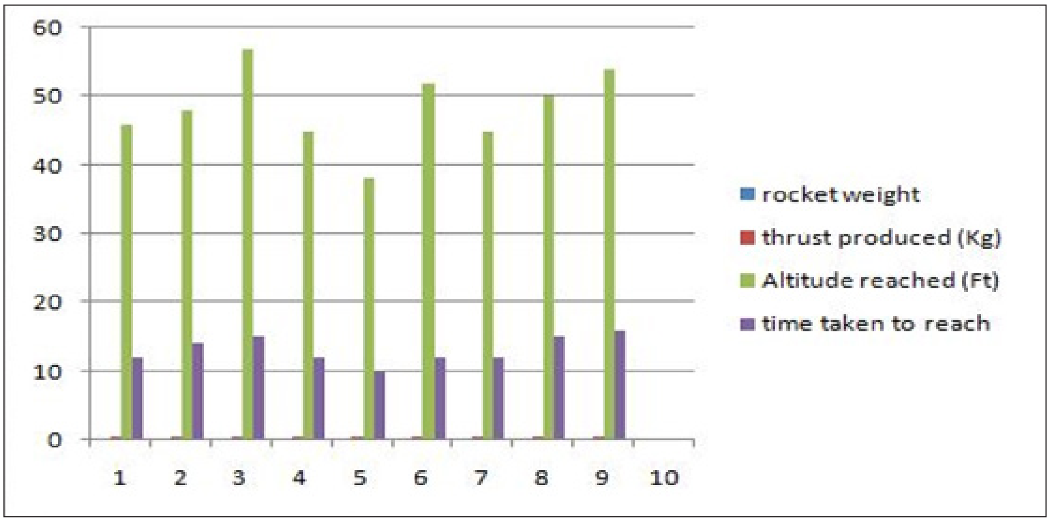


**Figure 3.Bar graph data of altitude of potassium nitrate, magnesium powder and sugar based fuel**

## Conclusion

In conclusion, the comparative analysis of the three distinct rocket fuel formulations—potassium nitrate and sugar (KN-Sugar), potassium nitrate, sulphur, charcoal, and iron rust (KNSCIR), and potassium nitrate, magnesium powder, and sugar—revealed varying degrees of performance in altitude reach and thrust generation. The KN-Sugar fuel showcased moderate performance, reaching a height of 57 feet with a peak thrust of 0.490 kilograms. On the other hand, the KNSCIR fuel exhibited superior performance, achieving an impressive altitude of 83 feet and generating a substantial thrust of 0.890 kilogrammes, outperforming the others in both aspects. The potassium nitrate, magnesium powder, and sugar fuel fell between the two, reaching a height of 57 feet with a thrust of 0.638 kilograms. While not achieving the highest altitude or thrust production, it demonstrated a balanced performance. Considering the overall results, the KNSCIR fuel formulation emerged as the most effective, showcasing exceptional capabilities for reaching greater altitudes and producing substantial thrust. However, the potassium nitrate, magnesium powder, and sugar formulation showed a promising balance between altitude and thrust. Further refinement and testing may reveal its potential for specific applications requiring a moderate combination of both factors. Nonetheless, the findings underline the superior performance of the KNSCIR formulation, making it a preferable choice for missions demanding higher altitudes and robust thrust capabilities in solid propellant rocket systems.

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