GB 2 308 849 discloses dihydro benzoxazine derivatives for use as anti-knock agents. However, the derivatives provide a significantly smaller increase in the RON of a fuel than is provided by NMA at similar treat rates.

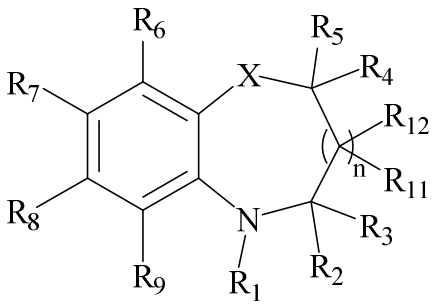
Accordingly, there remains a need for additives for a fuel for a spark-ignition internal combustion engine that are able to achieve anti-knock effects, e.g. at least comparable anti-knock effects to NMA, while mitigating at least some of the problems highlighted above.

Summary of the Invention

Surprisingly, it has now been found that an additive having a chemical structure comprising a 6-membered aromatic ring sharing two adjacent aromatic carbon atoms with a 6- or 7-membered saturated heterocyclic ring, the 6- or 7-membered saturated heterocyclic ring comprising a nitrogen atom directly bonded to one of the shared carbon atoms to form a secondary amine and an atom selected from oxygen or nitrogen directly bonded to the other shared carbon atom, the remaining atoms in the 6- or 7-membered heterocyclic ring being carbon, provides a substantial increase to the octane number, particularly the RON, of a fuel for a spark-ignition internal combustion engine.

Accordingly, the present disclosure provides a fuel composition for a spark-ignition internal combustion engine, the fuel composition comprising an additive having a chemical structure comprising a 6-membered aromatic ring sharing two adjacent aromatic carbon atoms with a 6- or 7-membered saturated heterocyclic ring, the 6- or 7-membered saturated heterocyclic ring comprising a nitrogen atom directly bonded to one of the shared carbon atoms to form a secondary amine and an atom selected from oxygen or nitrogen directly bonded to the other shared carbon atom, the remaining atoms in the 6- or 7-membered heterocyclic ring being carbon (hereinafter described as an “octane-boosting additive”).

Also provided is a fuel composition for a spark-ignition internal combustion engine, the fuel composition comprising an octane-boosting additive having the formula:



where: R_1 is hydrogen;

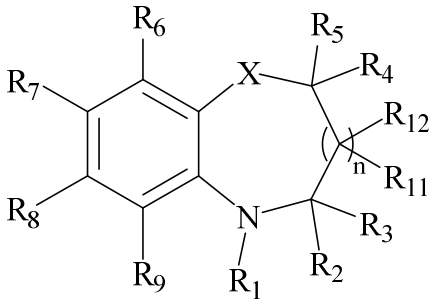
R_2, R_3, R_4, R_5, R_{11} and R_{12} are each independently selected from hydrogen, alkyl, alkoxy, alkoxy-alkyl, secondary amine and tertiary amine groups;

R_6, R_7, R_8 and R_9 are each independently selected from hydrogen, alkyl, alkoxy, alkoxy-alkyl, secondary amine and tertiary amine groups;

X is selected from -O- or -NR_{10}-, where R_{10} is selected from hydrogen and alkyl groups; and

n is 0 or 1.

In one aspect, the present disclosure provides a fuel composition for a spark-ignition internal combustion engine, the fuel composition comprises an additive having the formula:



where: R_1 is hydrogen;

R_2, R_3, R_4, R_5, R_{11} and R_{12} are each independently selected from hydrogen, alkyl, alkoxy, alkoxy-alkyl, secondary amine and tertiary amine groups;

R_6, R_7, R_8 and R_9 are each independently selected from hydrogen, alkyl, alkoxy, alkoxy-alkyl, secondary amine and tertiary amine groups;

X is selected from -O- or -NR_{10}-, where R_{10} is selected from hydrogen and alkyl groups; and

n is 0 or 1;

wherein at least one of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} is selected from a group other than hydrogen.

In another aspect, the present disclosure provides a process for producing a fuel composition of the present disclosure, the process comprising the step of combining a fuel for a spark-ignition internal combustion engine with an octane-boosting additive described herein.

In another aspect, the present disclosure provides the use of an octane-boosting additive described herein in a fuel for a spark-ignition internal combustion engine. In another aspect, the present disclosure provides the use of an octane-boosting additive described herein for increasing the octane number of a fuel for a spark-ignition internal combustion engine. In a further aspect, the present disclosure provides the use of an additive described herein for improving the auto-ignition characteristics of a fuel, *e.g.* by reducing the propensity of the fuel for at least one of auto-ignition, pre-ignition, knock, mega-knock and super-knock, when used in a spark-ignition internal combustion engine.

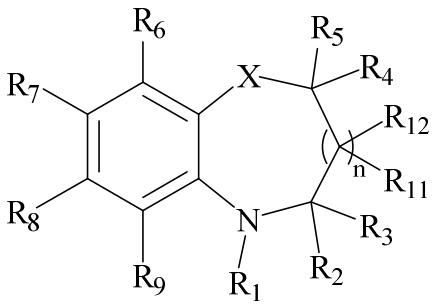
In another aspect, the present disclosure provides a method for increasing the octane number of a fuel for a spark-ignition internal combustion engine, said method comprising blending an additive described herein with the fuel. In another aspect, the present disclosure provides a method for improving the auto-ignition characteristics of a fuel, *e.g.* by reducing the propensity of a fuel for at least one of auto-ignition, pre-ignition, knock, mega-knock and super-knock, when used in a spark-ignition internal combustion engine, said method comprising blending an octane-boosting additive described herein with the fuel.

Brief Description of the Figures

Figures 1a-c show graphs of the change in octane number (both RON and MON) of fuels when treated with varying amounts of an octane-boosting additive described herein. Specifically, Figure 1a shows a graph of the change in octane number of an E0 fuel having a RON prior to additisation of 90; Figure 1b shows a graph of the change in octane number of an E0 fuel having a RON prior to additisation of 95; and Figure 1c shows a graph of the change in octane number of an E10 fuel having a RON prior to additisation of 95.

Claims:

1. A fuel composition for a spark-ignition internal combustion engine, the fuel composition comprises an additive having the formula:



where: R_1 is hydrogen;

R_2, R_3, R_4, R_5, R_{11} and R_{12} are each independently selected from hydrogen, alkyl, alkoxy, alkoxy-alkyl, secondary amine and tertiary amine groups;

R_6, R_7, R_8 and R_9 are each independently selected from hydrogen, alkyl, alkoxy, alkoxy-alkyl, secondary amine and tertiary amine groups;

X is selected from -O- or -NR_{10}-, where R_{10} is selected from hydrogen and alkyl groups; and

n is 0 or 1;

wherein at least one of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} is selected from a group other than hydrogen.

2. A fuel composition according to claim 1~~2~~,wherein R_2, R_3, R_4, R_5, R_{11} and R_{12} are each independently selected from hydrogen and alkyl groups, preferably from hydrogen, methyl, ethyl, propyl and butyl groups, more preferably from hydrogen, methyl and ethyl, and even more preferably from hydrogen and methyl.

3. A fuel composition according to claim 2 or claim 3, wherein R_6, R_7, R_8 and R_9 are each independently selected from hydrogen, alkyl and alkoxy groups, preferably from hydrogen, methyl, ethyl, propyl, butyl, methoxy, ethoxy and propoxy groups, more preferably from hydrogen, methyl, ethyl and methoxy, and even more preferably from hydrogen, methyl and methoxy.

4. A fuel composition according to any of claims 2 to 4, wherein at least one of R_6, R_7, R_8 and R_9 is selected from a group other than hydrogen.

5. A fuel composition according to any of claims 2 to 5, wherein no more than five, preferably no more than three, and more preferably no more than two, of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} are selected from a group other than hydrogen.

6. A fuel composition according to any of claims 2 to 6, wherein at least one of R_2 and R_3 is hydrogen, and preferably wherein R_2 and R_3 are hydrogen.

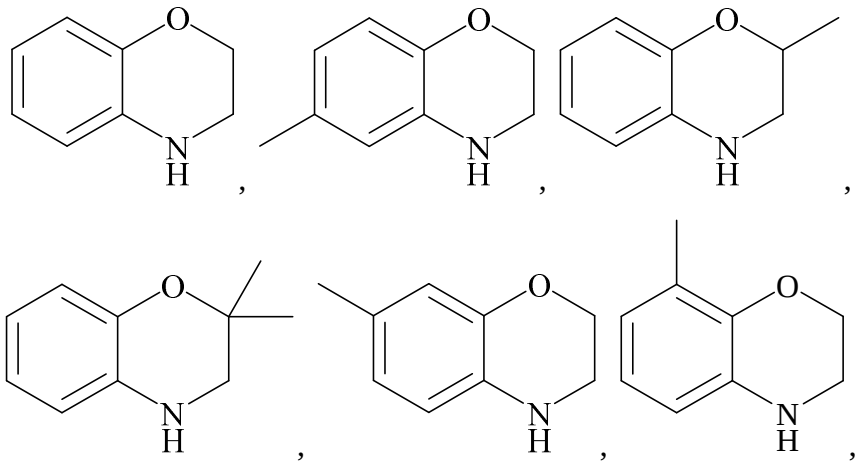
7. A fuel composition according to any of claims 2 to 7, wherein at least one of R_4, R_5, R_7 and R_8 is selected from methyl, ethyl, propyl and butyl groups and the remainder of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} are hydrogen, and preferably wherein at least one of R_7 and R_8 are selected from methyl, ethyl, propyl and butyl groups and the remainder of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} are hydrogen.

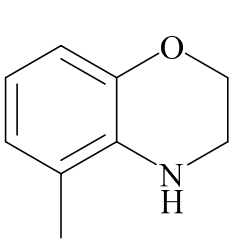
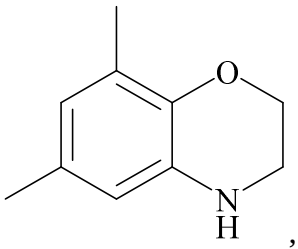
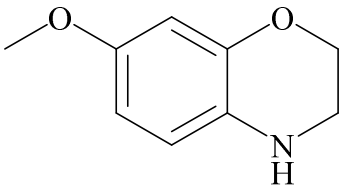
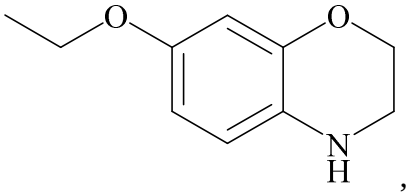
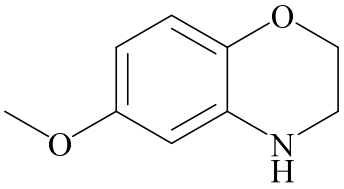
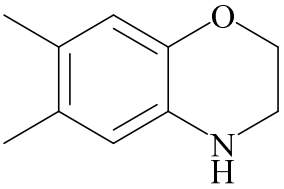
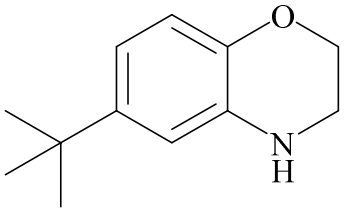
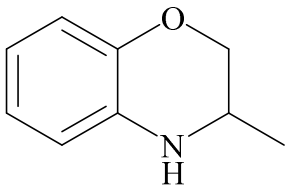
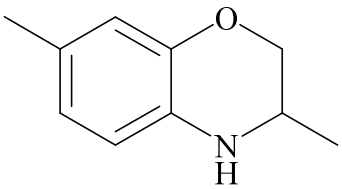
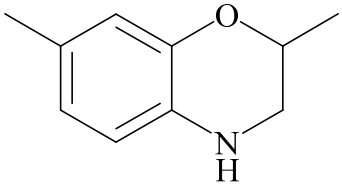
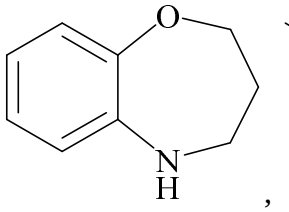
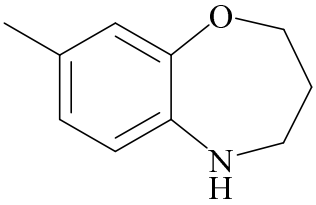
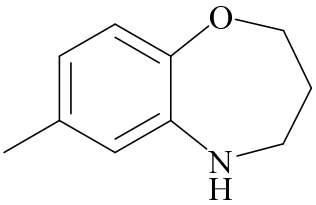
8. A fuel composition according to claim 8, wherein at least one of R_4, R_5, R_7 and R_8 is a methyl group and the remainder of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} are hydrogen, and preferably wherein at least one of R_7 and R_8 is a methyl group and the remainder of R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{11} and R_{12} are hydrogen.

9. A fuel composition according to any of claims 2 to 9, wherein X is -O- or -NR_{10}-, where R_{10} is selected from hydrogen, methyl, ethyl, propyl and butyl groups, preferably from hydrogen, methyl and ethyl groups, and even more preferably is hydrogen, and preferably wherein X is -O-.

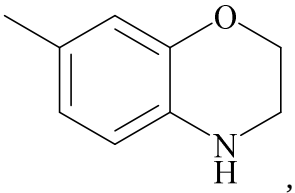
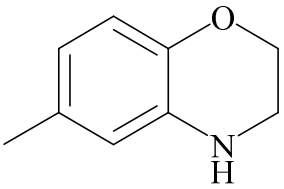
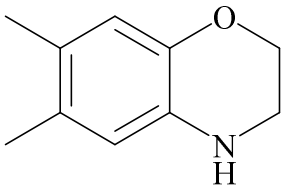
10. A fuel composition according to any of claims 2 to 10, wherein n is 0.

11. A fuel composition according to any preceding claim, wherein the additive is selected from:




,

,

,

,

,

,

,

,

,

,

,

, and

,

and preferably from:


,

, and

.

12. A fuel composition according to any preceding claim, wherein the additive is present in the fuel composition an amount of up to 20 %, preferably from 0.1 % to 10 %, more preferably from 0.2 % to 5 %, even more preferably from 0.25 % to 2 %, and even more preferably still from 0.3 % to 1 %, weight additive / weight base fuel.

13. A fuel composition according to any preceding claim, further comprising ethanol present in the fuel composition in an amount of up to 85 %, preferably from 1 % to 30 %, more preferably from 3 % to 20 %, and even more preferably from 5 % to 15 %, by volume.

14. A process for producing a fuel composition of any of claims 1-14, the process comprising combining a fuel for a spark-ignition internal combustion engine with an additive as defined in any of claims 1-14.

15. Use of an additive as defined in any of claims 1-14 in a fuel for a spark-ignition internal combustion engine.

16. Use of an additive as defined in any of claims 1-14 for increasing the octane number of a fuel for a spark-ignition internal combustion engine.

17. Use of an additive as defined in any of claims 1-14 for improving the auto-ignition characteristics of a fuel, *e.g.* by reducing the propensity of a fuel for at least one of auto-ignition, pre-ignition, knock, mega-knock and super-knock, when used in a spark-ignition internal combustion engine.

18. A method for increasing the octane number of a fuel for a spark-ignition internal combustion engine, said method comprising blending an additive as defined in any of claims 1-14 with the fuel.

19. A method for improving the auto-ignition characteristics of a fuel, *e.g.* by reducing the propensity of a fuel for at least one of auto-ignition, pre-ignition, knock, mega-knock and super-knock, when used in a spark-ignition internal combustion engine, said method comprising blending an additive as defined in any of claims 1-14 with the fuel.