Core Blending Efficiency Improvements Achieved In Continuous Pressing of Particleboard

Dr Raymond J. Roberts

RJRoberts Consulting Pty Ltd

Abstract

In previous papers presented at this symposium (Roberts 2011 Part B) the author demonstrated the inefficiency of high speed particleboard blenders caused by surface energy considerations and by destruction of flake geometry and how this might be improved. This paper presents the results of three full scale plant trials using Rezex A in conjunction with modifications to high speed PAL core blenders. The results show that either significant resin reductions or density reductions can occur that will substantially reduce the costs of producing particleboard. The results also show that MOR's can be significantly improved with the use of the technology. In previous papers the author using light microscopy showed that both resin distribution and flake geometry can be improved by using Rezex A and manipulating blender dwell times by changing horn and flap configurations. The results from full scale plant trials verify at a plant scale the predictions made in the previous papers.

Introduction

As a result of a detailed study into particleboard machinability issues caused by chipout in laminated particleboard it was determined that the overall problem was caused by poor spreading of resin in high speed PAL blenders (Roberts 2011 Part A). This was as a result of the very high interfacial energy between the aqueous based amino resins and the surface of the dried flake due to pyrolysis of wood resins to fatty acids during drying which are very hydrophobic. This in turn led to a much larger study on the "efficiency" of such blenders.

The blending of core flake in particleboard manufacture is a complex process involving the spreading of resins over usually non-wetting surfaces. Due to it's mechanical nature this invariably involves the destruction of flake with consequential potential loss of physical properties, in particular bending modulus. It was also shown that such blending results in the smallest flake having the most resin and least resin variability and the largest flake having the least resin coverage and the most variability.

High speed blenders including PAL type blenders supposedly rely on mechanical "wiping" of resin from one flake to another after resin injection. To optimise blending, operators manipulate flake dwell times using complex models involving motor current to set paddle and horn angles as well as the resistance of the outfeed flap. It would appear that up till 2011 little effort has gone into the actual physics of blending and how optimal resin spread can be achieved.

Currently one solution appears to be to add an additional blender in the hope of further improving resin spread however as wetting occurs over such short time scales all that these second blenders achieve is further damage to flake, with no additional resin spread and considerable extra capital cost for no gain. Another solution is to buy newer more expensive blenders however these also rely on mechanical spreading of the fluid irrespective of how small the droplet size they can achieve (usually through shear forces) and take no consideration of the afore mentioned surface energy considerations of spreading liquids on hydrophobic surfaces such as flake.

Roberts 2011 concluded that in a study on mean resin distribution and variation in resin distribution at an individual flake level with the use of the multi-phase wetting system Rezex A, that resin is more effectively and evenly distributed over larger flake. With the modification to blending conditions associated with the use of Rezex A, there was a substantial improvement in flake geometry while still maintaining and improving resin distribution on the larger flake.

In plant trials in Australia, Roberts 2011 Part B stated that the use of Rezex A allowed far more flexibility in the setups of blenders especially horn and paddle position, flap settings and injection nozzle position. Another benefit that was demonstrated was the reduction of motor current as a result of reducing flake dwell time in the blenders saving power and above all allows for modifications to blender setups to improve flake geometry and resin spread.

It was also shown that average resin coverage of larger flake substantially increased and variability in resin distribution on larger flake was reduced with the use of Rezex A. This gave potential for reductions in resin usage or reductions in density and hence amount of wood used each of which could lead to significant cost savings.

In these initial trials physical properties were either as good as or better than normal production property data. However no statistical inference could be drawn as the only property tests that were done during these initial trials was for compliance testing.

This paper reports on three full scale plant trials that were conducted at large particleboard operations In Europe and South East Asia each with continuous presses and PAL type blenders, two of the operations in fact having two core blenders. The results unequivocally show that what was predicted in Roberts 2011 Part B was achieved at a large plant level.

Materials and Methods

Similar trials were run at three plants, two producing approximately 2,000 m^3 per day and one producing approximately 1,000 m^3 per day. Each of the larger plants had two PAL core blenders the first where resin was added in the standard method with air assisted injection nozzles, and the second blender supposedly improving resin distribution. However in both cases the second blender was effectively an expensive conveyor where the horns were up to 20° advanced and the outfeed flap permanently open because in both cases there was no improvement in resin use at all with the second core blender. In all the trials the second core blender was again set up with advanced horn settings and flap open. The smaller of the plants only had one PAL core blender.

The two larger plants had very low quality furnish with very little fresh ring mill type flake. The third plant had the primary source of flake from ring mill type flakers with chips from small round wood with bark on.

The Rezex A was added to the resin using the existing glue kitchens, no additional capital or expenditure was required to run the trials.

The trial plan was designed in such a way as to be able to draw a statistical inference, while minimising downtime in the adjustment of blender settings as well as minimising the chance of producing unsaleable board. As a result the design was not randomized. Analysis of variance (ANOVA) was used to analyse data. All data were checked to ensure that it complied with the assumptions of ANOVA, i.e. normality with constant variance. Statistical computation was carried out using Genstat (Lawes Agricultural Trust). The resin reduction results were analysed with density as a covariate where a linear regression was used to estimate very slight corrections in the property data. This obviously was not required in the density reduction trials where of course density was a factor.

The design of the plant trials was according to Tables 1 & 2 however the design could be nested as there were common treatments between the resin reduction and density reduction trials. Therefore the trials were carried out over 4 day shifts, see Table 4 where the blender setups were as follows:

Day 1. Horns normal/Flap closed

Day 2. Horns normal/Flap open

Day 3. Horns advanced/Flap closed

Day 4. Horns advanced/Flap open

This design resulted in only one period of downtime that being the beginning of Day 3 where the blender horns were changed. The blender horns were not adjusted between Days 3 & 4 however the flap was kept closed. Board made in all three plants during these night shifts was adequate and saleable saving two hours downtime at the end of Day 3 and two hours at the beginning of Day 4.

The level of advancement of the horns in the mixing zones was plant specific and proprietary information however were significantly advanced from the manufacturers recommended settings (Table 3). The determination of this was based on experience with different types of flake, species of flake and the size of the blender.

a) Resin reduction (density being constant)

	Blender	Rezex Dose	Resin reduction
N1	Flap closed/Horns Normal	0	0%
N2	Flap open/Horns Normal	0	0
N3	Flap closed/Horns Advanced	0	0
N4	Flap open/Horns Advanced	0	0
R1	Flap closed/Horns Normal	0.2	0
R2	Flap closed/Horns Normal	0.1	0
R3	Flap closed/Horns Normal	0.2	5%
R4	Flap closed/Horns Normal	0.1	5%
R5	Flap closed/Horns Normal	0.2	10
R6	Flap closed/Horns Normal	0.1	10
R7	Flap closed/Horns advanced	0.2	0
R8	Flap closed/Horns advanced	0.1	0
R9	Flap closed/Horns advanced	0.2	5%
R10	Flap closed/Horns advanced	0.1	5
R11	Flap closed/Horns advanced	0.2	10
R12	Flap closed/Horns advanced	0.1	10
R13	Flap open/Horns advanced	0.2	0
R14	Flap open/Horns advanced	0.1	0
R15	Flap open/Horns advanced	0.2	5%
R16	Flap open/Horns advanced	0.1	5%
R17	Flap open/Horns advanced	0.2	10
R18	Flap open/Horns advanced	0.1	10
R19	Flap open/Horns normal	0.2	0
R20	Flap open/Horns normal	0.1	0
R21	Flap open/Horns normal	0.2	5%
R22	Flap open/Horns normal	0.1	5%
R23	Flap open/Horns normal	0.2	10
R24	Flap open/Horns normal	0.1	10

Table 1, Resin reduction treatments

b) Density reduction (resin loading being constant)

	Blender	Rezex Dose	Density reduction
N1	Flap closed/Horns Normal	0	0%
N2	Flap open/Horns Normal	0	0
N3	Flap closed/Horns Advanced	0	0
N4	Flap open/Horns Advanced	0	0
D1	Flap closed/Horns Normal	0.2	0
D2	Flap closed/Horns Normal	0.1	0
D3	Flap closed/Horns Normal	0.2	5%
D4	Flap closed/Horns Normal	0.1	5%
D5	Flap closed/Horns Normal	0.2	10
D6	Flap closed/Horns Normal	0.1	10
D7	Flap closed/Horns advanced	0.2	0
D8	Flap closed/Horns advanced	0.1	0
D9	Flap closed/Horns advanced	0.2	5%
D10	Flap closed/Horns advanced	0.1	5
D11	Flap closed/Horns advanced	0.2	10
D12	Flap closed/Horns advanced	0.1	10
D13	Flap open/Horns advanced	0.2	0
D14	Flap open/Horns advanced	0.1	0
D15	Flap open/Horns advanced	0.2	5%
D16	Flap open/Horns advanced	0.1	5%
D17	Flap open/Horns advanced	0.2	10
D18	Flap open/Horns advanced	0.1	10
D19	Flap open/Horns normal	0.2	0
D20	Flap open/Horns normal	0.1	0
D21	Flap open/Horns normal	0.2	5%
D22	Flap open/Horns normal	0.1	5%
D23	Flap open/Horns normal	0.2	10
D24	Flap open/Horns normal	0.1	10

Table 2, Density reduction treatments

Blender settings

Paddle and Horn positions particleboard core blenders

Blender zone	Horn position normal	Horn position (Advanced)
Inlet paddles	+40°	+40°
Injection zone	0°	0°
Mixing zone 1	0°	+α°
Mixing zone 2	0°	+α °
Outlet zone 1	-10°	+α °
Outlet zone 2	-10°	-10°

Table 3, paddle and horn positions

	Treatments Day 1	Resin	Density	Rezex A %
Normal		Normal	Normal	**0**
R1	Horns Normal/ Flap closed	Normal	Normal	0.2
D3	Horns Normal/ Flap closed	Normal	-5%	0.2
R3	Horns Normal/ Flap closed	-5%	Normal	0.2
R5	Horns Normal/ Flap closed	-10%	Normal	0.2
D4	Horns Normal/ Flap closed	Normal	-5%	0.1
R2	Horns Normal/ Flap closed	Normal	Normal	0.1
R4	Horns Normal/ Flap closed	-5%	Normal	0.1
R6	Horns Normal/ Flap closed	-10%	Normal	0.1

	Treatments Day 2	Resin	Density	Rezex A %
Normal	Horns normal/Flap open	Normal	Normal	**0**
R19	Horns normal/Flap open	Normal	Normal	0.2
D21	Horns normal/Flap open	Normal	-5%	0.2
R21	Horns normal/Flap open	-5%	Normal	0.2
R23	Horns normal/Flap open	-10%	Normal	0.2
R20	Horns normal/Flap open	Normal	Normal	0.1
D22	Horns normal/Flap open	Normal	-5%	0.1
R22	Horns normal/Flap open	-5%	Normal	0.1
R24	Horns normal/Flap open	-10%	Normal	0.1

	Treatments Day 3	Resin	Density	Rezex A %
Normal	Horns advanced/ Flap closed	Normal	Normal	0
R7	Horns advanced/ Flap closed	Normal	Normal	0.2
D9	Horns advanced/ Flap closed	Normal	-5%	0.2
R9	Horns advanced/ Flap closed	-5%	Normal	0.2
R11	Horns advanced/ Flap closed	-10%	Normal	0.2
D10	Horns advanced/ Flap closed	Normal	-5%	0.1
R8	Horns advanced/ Flap closed	Normal	Normal	0.1
R10	Horns advanced/ Flap closed	-5%	Normal	0.1
R12	Horns advanced/ Flap closed	-10%	Normal	0.1

	Treatments Day 4	Resin	Density	Rezex A %
Normal	Horns advanced/Flap open	Normal	Normal	0
R13	Horns advanced/Flap open	Normal	Normal	0.2
D15	Horns advanced/Flap open	Normal	-5%	0.2
R15	Horns advanced/Flap open	-5%	Normal	0.2
R17	Horns advanced/Flap open	-10%	Normal	0.2
D16	Horns advanced/Flap open	Normal	-5%	0.1
R14	Horns advanced/Flap open	Normal	Normal	0.1
R16	Horns advanced/Flap open	-5%	Normal	0.1
R18	Horns advanced/Flap open	-10%	Normal	0.1

Table 4, Treatments on a daily basis. Red treatments indicate same data used for similarly numbered density trial.

Results

Results from the trial are presented in the form of horizontal bar charts with least significant different bars at the 95% confidence level (Figures 1- 12). They show the effects of blender setup and Rezex A dose with either resin loading reduction or density reduction on IB and MOR values.

In Plant A when Rezex A was added without any change in resin loading or density; there was no significant difference in MOR from normal production values. However with both Plants B & C there was a significant increase in the MOR with the addition of Rezex A at 0.2% with normal resin and density levels. The increase in the case of Plant B was 1.7 mPa (from 12 to 13.7mPa) i.e. a 14.2% increase and with Plant C the increase was from 10.13 to 11.2mPa i.e. 10.3%.

Plant A with a 10% resin reduction, there were four treatments that achieved statistically similar MOR values to normal production. They were treatments R6 & R12 both with a Rezex A addition of 0.1% and R23 & R5 with a Rezex A addition of 0.2% (Figure 1). There were 3 additional treatments that achieved a 5% reduction in resin loading without any effect on MOR values (Treatments R4, R10 & R21).

With a 10% resin reduction in Plant B, 0.2% addition of Rezex A and with blender settings Horns normal/Flap open; MOR's increased from 12.01mPa to 13.34mPa over an 11% increase. With a 5% reduction and with the addition of Rezex A at 0.1% the value of MOR's increased from 12.0 to 13.44mPa and increase of 12%, note that this is statistically similar to that achieved with 0.2% Rezex A showing that 0.1% is adequate in this case. There were 5 treatments that achieved MOR values statistically similar to Normal production with 10% less resin, Treatments R24, R6 and R12 and with the addition of 0.1% Rezex A and with the addition of 0.2% Rezex A Treatments R3 and R11 (Figure 5). There were 4 additional treatments that achieved a 5% resin reduction with no effect on MOR values Treatments R21, R9, R5 & R4.

In Plant C with a 5% resin reduction with the addition of 0.1% Rezex A and with blender modifications (Treatments R16 & R10) achieved significant improvements in MOR's of over 7%. There were eight treatments than enabled resin loadings to be reduced by 10% and have no statistical effect on MOR. There were a further six treatments that enabled resin loadings to be reduced by 5% and have no statistical effect on MOR values (Figure 9).

Thus in all of the plants it was possible to reduce resin loading by 10% with no statistical difference in MOR values.

In Plants A & B there was no significant change in IB values between normal production and with the addition of Rezex A with no blender changes. However in Plant C there was a significant increase in IB's with the addition of Rezex A (with no changes to the blender) over normal production from 0.443 to 0.52 mPa an increase of 17.4%.

Regarding resin reduction and effect on IB's, in Plant A a resin reduction of 10% was achieved with no statistical difference from normal production with the addition of 0.1% Rezex A with normal blender settings and 0.2% Rezex A with Horns advanced/Flap closed. It was possible to reduce resin loadings by 10% with IB values still above 0.45mPa with a further 4 treatments (Figure 2).

With Plant B it was possible to reduce resin loadings by 10% with the addition of 0.2% Rezex with normal blender settings, while statistically lower than normal production, however with IB values above 0.45mPa (Figure 6).

With Plant C there were seven different treatments that resulted in statistically similar IB values to normal production however with 10% less resin using Rezex A and various blender settings, and an additional 6 with 5% lower resin loadings (Figure 10).

In Plant A reducing density with any blender modification or with the addition of Rezex A, had a significant negative effect on MOR. However the normal board had a relatively low density in the first place i.e 650 kgs/m^3 (Figure 6).

With Plant B however it was possible to reduce density by 10% with no effect on MOR values with the addition of 0.1 & 0.2% Rezex A and with blender settings; Horns normal/Flap closed (Treatments D6 & D5). There were five additional treatments that achieved a 5% density reduction; Treatments D22, D21, D3, D9 & D4 (Figure 7).

With Plant C it was again possible to reduce density by 5% with no effect on MOR values with four treatments, D21, D16, D10 & D22 the first being at 0.2% Rezex A and the latter three at 0.1% Rezex A addition (Figure 11). The addition of 0.1% Rezex A with various blender settings shows the flexibility in blender setups with the use of Rezex A; Horns advanced/Flap closed, Horns advanced/Flap open and Horns normal/Flap open. It was not possible to produce adequate board at -10% density.

The effect of density reduction on IB's was again site specific. In Plant A reducing density by 5% with the use of Rezex A and with changes to blender setups, IB values were significantly reduced compared to normal production however the values were still well above product standard limits, the reductions being only around 50kPa (Figure 4).

The effect of a 5% reduction in density combined with the use of Rezex A at 0.1% on Plant B was to reduce IB's by about 70kPa although still substantially above any standard specification limit (Figure 8).

In Plant C it was possible to reduce density by 5% without any significant effect on the value of IB's by varying blender settings and with the addition of Rezex A with blender settings; Horns advanced/Flap closed, Horns advanced/Flap open, Horns normal/Flap closed and Horns normal/Flap open, in other words all of the possible blender configurations (Figure 12). This again shows the flexibility of blender settings with the use of Rezex A.

Table 5 shows a summary of the resin reduction treatments. It shows that all three plants were able to achieve 5 & 10% reduction in resin loadings from their current usage with an addition of Rezex A at a dose rate of 0.1% w/w on flake weight with blender horns advanced and the blender flap closed. All three plants were able to achieve 10% resin reduction with normal blender settings with the addition of both 0.1 & 0.2% Rezex A. In plants B & C with horns normal/flap open 5% resin savings were achieved with 0.1% addition of Rezex A.

Plant C was able to achieve 10% resin savings with the most aggressive blender setup i.e. horns advanced/flap open with both 0.1 & 0.2% addition of Rezex A as well as a 5% reduction in resin with the same blender settings with the addition of 0.1% Rezex A. This setting was not run in Plant B.

Table 6 shows the summary of density reduction treatments, Plant A was not able to achieve any density reduction, whereas Plant B could achieve a 10% density reduction and Plant B a 5% density reduction

<u>Conclusions</u>

It was shown in previous papers that with blender modifications and the use of Rezex A, that the size of the flake in the larger fractions increased in width. Due to the fact that flake is much stronger longitudinally than laterally due to the orientation of wood fibres, when it breaks it reduces firstly in width then length. Therefore if one is to reduce flake breakage, the effect will be an increase in flake width which was previously demonstrated. It was also shown that there was an increase in the proportion of larger flake with the use of Rezex A and with blender modifications (Roberts 2011 Parts A & B).

It was also shown in previous papers that with the use of Rezex A, resin is more effectively and evenly distributed over larger flake than that with the modification of blending conditions alone. With the use of Rezex A, there was a substantial improvement in flake geometry while still maintaining and improving resin distribution on the larger flake. It was therefore hypothesised that this improvement in flake geometry and improved resin spread and reduced resin spread variability would increase bending modulus properties, (MOR) which then could lead to cost savings in the form of reduced resin loadings or reduced density of the panel.

This hypothesis was proven absolutely correct as demonstrated in large scale plant trials in Plants A, B & C.

All three plants achieved both 5 & 10% resin savings with 0.1% Rezex A with both Horns advanced/Flap closed and Horns normal/Flap closed. These were the most successful treatments with the addition of Rezex A in terms of reducing resin loading.

Plants B achieved a density reduction of 10% and Plant C achieved a density reduction of 5% .

On Plant B the treatment regime Horns advanced/Flap open was not tried which in hindsight was a mistake as this was a successful treatment in Plant C which had similar furnish to Plant B

It was shown that not only could resin loading be reduced there was also an *increase* in MOR properties verifying what was hypothesised in 2011. IB values are not the limiting factor in board properties. It is usually MOR which really limits the physical properties of particleboard. As long as the tensile properties pass the necessary standards, then this is all that is required.

In fact in most if not all of the plants that I have visited around the world, IB values are usually too high indicating over use of resin. This is usually the case because the extra resin is used to compensate for lower MOR values as a result of poor quality flake. Therefore if MOR values can be improved by the use of Rezex A in conjunction with with blender modifications then resin loadings can be reduced as has been shown by these trials.

It was previously shown that the use of Rezex A allows far more flexibility in the set-ups of blenders such that injection nozzle position is not a key factor. Various horn and flap positions resulted in improved properties while reducing motor current and saving power also further demonstrating the flexibility in blender setups that can be achieved with the use of Rezex A. This flexibility is again demonstrated in setups such that in the three plants, identical setups achieved similar results (Table 15). Each of the plants had completely different furnish, different resins and different pressing conditions, yet there were more identical treatments achieving the same result than dissimilar treatments.

From Table 15 it is shown that of the 29 successful treatments between the plants, 9 had blender settings with horn angles advanced, Flap closed; 11 with normal blender settings, 6 with normal horn angles/ flap open and 3 with both advanced horn angles/ flap open, bearing in mind that Plant B did not run this treatment. Another significant point is that achieving 10% resin saving is possible with all four of the blender. Of the 13 treatments that resulted in 10% resin saving, 6 were with normal blender settings, 3 with horns advanced/flap closed, and two each with horns advanced/flap open and horns normal/flap open.

Until now the operation of high speed PAL type blenders involved complex relationships of base load and running motor current resulting from horn angle, paddle angle and flap position all based on the premise that resin is wiped from flake to flake. The theory being the greater the dwell time the greater the wiping of resins in such a manner. Of course in this scenario the greater the dwell time, the greater the physical damage to flake and hence potential reduction of bending modulus properties of the particleboard, which was proven in 2011.

It has been shown that using the physics of wetting and an understanding of surface energy considerations i.e. the interfacial energy between the resin and the flake surface, it is possible to optimise the spreading of resins, improve flake geometry, use less resins or less blended flake and achieve far better bending modulus properties. This of course will lead to significant cost savings which otherwise would not be achievable without the use of Rezex A.

It is also very interesting to note that where flake quality is poor, there were the biggest improvements in MOR with the use of Rezex A associated with blender modifications. With poor quality flake it was possible to reduce density of the board whereas with higher quality flake it was not possible (albeit starting from a low base). As most of the particleboard that is currently being made in the world uses poor quality furnish, this technology is very significant in being able to improve the production costs in manufacture of particleboard while achieving resin or blended flake savings with at least equal board properties.

In the recent past in order to improve blending, hardware manufacturers have encouraged the use of a second blender. This is at significant capital cost not to mention disruptions to plant operations. Usually these additional blenders do not achieve what was originally wanted i.e. resin savings. All that is achieved is further destruction of flake at the expense of bending modulus properties. However as has been shown in this paper, it is possible to achieve substantial resin savings without any additional capital cost with the use of Rezex A

References

Roberts R. J. *Blending efficiency Part A, Solving the problem of chipout in laminated particleboard.*

Washington State University International Wood Composites Symposium Seattle WA 2011

Roberts R. J. Blending efficiency Part B, *Core blending and how to improve it.*

Washington State University International Wood Composites Symposium Seattle WA 2011

Plant	**Treatment**	**Horn position**	**Flap position**	**Rezex A dose**	**Resin reduction**
A	**R12**	**Advanced**	**Closed**	**0.10%**	**10%**
B	**R12**	**Advanced**	**Closed**	**0.10%**	**10%**
C	**R12**	**Advanced**	**Closed**	**0.10%**	**10%**
C	*R11*	*Advanced*	*Closed*	*0.20%*	*10%*
A	**R10**	**Advanced**	**Closed**	**0.10%**	**5%**
B	**R10**	**Advanced**	**Closed**	**0.10%**	**5%**
C	**R10**	**Advanced**	**Closed**	**0.10%**	**5%**
B	*R9*	*Advanced*	*Closed*	*0.20%*	*5%*
C	*R9*	*Advanced*	*Closed*	*0.20%*	*5%*
C	**R18**	**Advanced**	**Open**	**0.10%**	**10%**
C	*R17*	*Advanced*	*Open*	*0.20%*	*10%*
C	**R16**	**Advanced**	**Open**	**0.10%**	**5%**
A	*R6*	*Normal*	*Closed*	*0.10%*	*10%*
B	*R6*	*Normal*	*Closed*	*0.10%*	*10%*
C	*R6*	*Normal*	*Closed*	*0.10%*	*10%*
A	**R5**	**Normal**	**Closed**	**0.20%**	**10%**
B	**R5**	**Normal**	**Closed**	**0.20%**	**10%**
C	**R5**	**Normal**	**Closed**	**0.20%**	**10%**
A	*R4*	*Normal*	*Closed*	*0.10%*	*5%*
B	*R4*	*Normal*	*Closed*	*0.10%*	*5%*
C	*R4*	*Normal*	*Closed*	*0.10%*	*5%*
B	**R3**	**Normal**	**Closed**	**0.20%**	**5%**
C	**R3**	**Normal**	**Closed**	**0.20%**	**5%**
C	*R24*	*Normal*	*Open*	*0.10%*	*10%*
A	**R23**	**Normal**	**Open**	**0.20%**	**10%**
B	*R22*	*Normal*	*Open*	*0.10%*	*5%*
C	*R22*	*Normal*	*Open*	*0.10%*	*5%*
A	**R21**	**Normal**	**Open**	**0.20%**	**5%**
B	**R21**	**Normal**	**Open**	**0.20%**	**5%**

Table 5 showing treatments that resulted in successful reductions in resin loading with the use of Rezex A and manipulation of blender settings.

The following treatments for **Plants B & C** gave density reductions with adequate IB and MOR values.

Plant	Treatment	Horn position	Flap position	Rezex A dose	Density reduction
B	D3	Normal	Closed	0.2%	5%
B	D4	Normal	Closed	0.1%	5%
B	D5	Normal	Closed	0.2%	10%
C	D10	Advanced	Closed	0.1%	5%
C	D16	Advanced	Open	0.1%	5%
C	D21	Normal	Open	0.2%	5%
C	D22	Normal	Open	0.1%	5%

Table 6 showing treatments that resulted in successful reductions in density with the use of Rezex A and manipulation of blender settings.

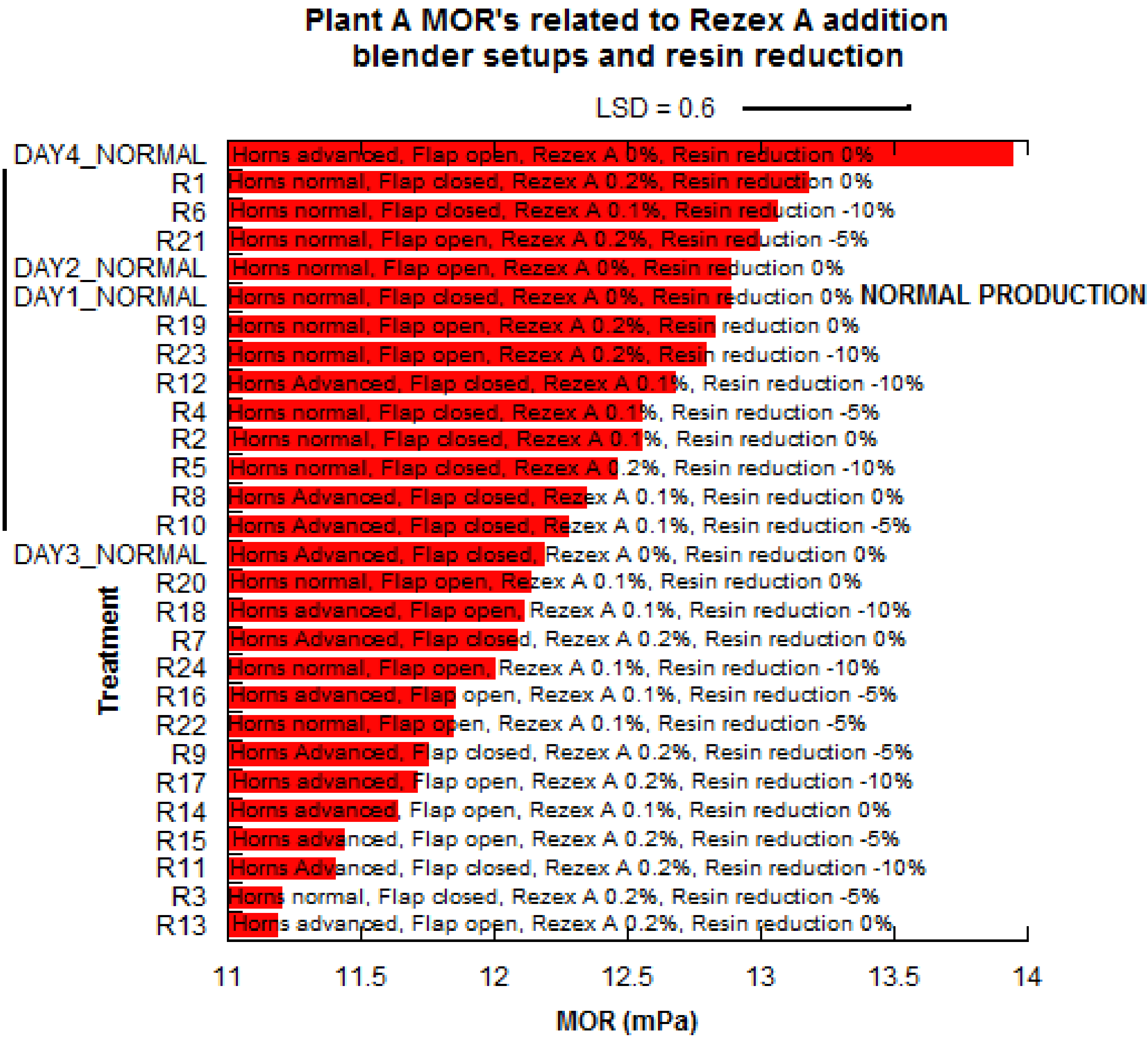

Figure 1, Plant A MOR values related to addition of Rezex A and various blender setups and reduced resin loadings.

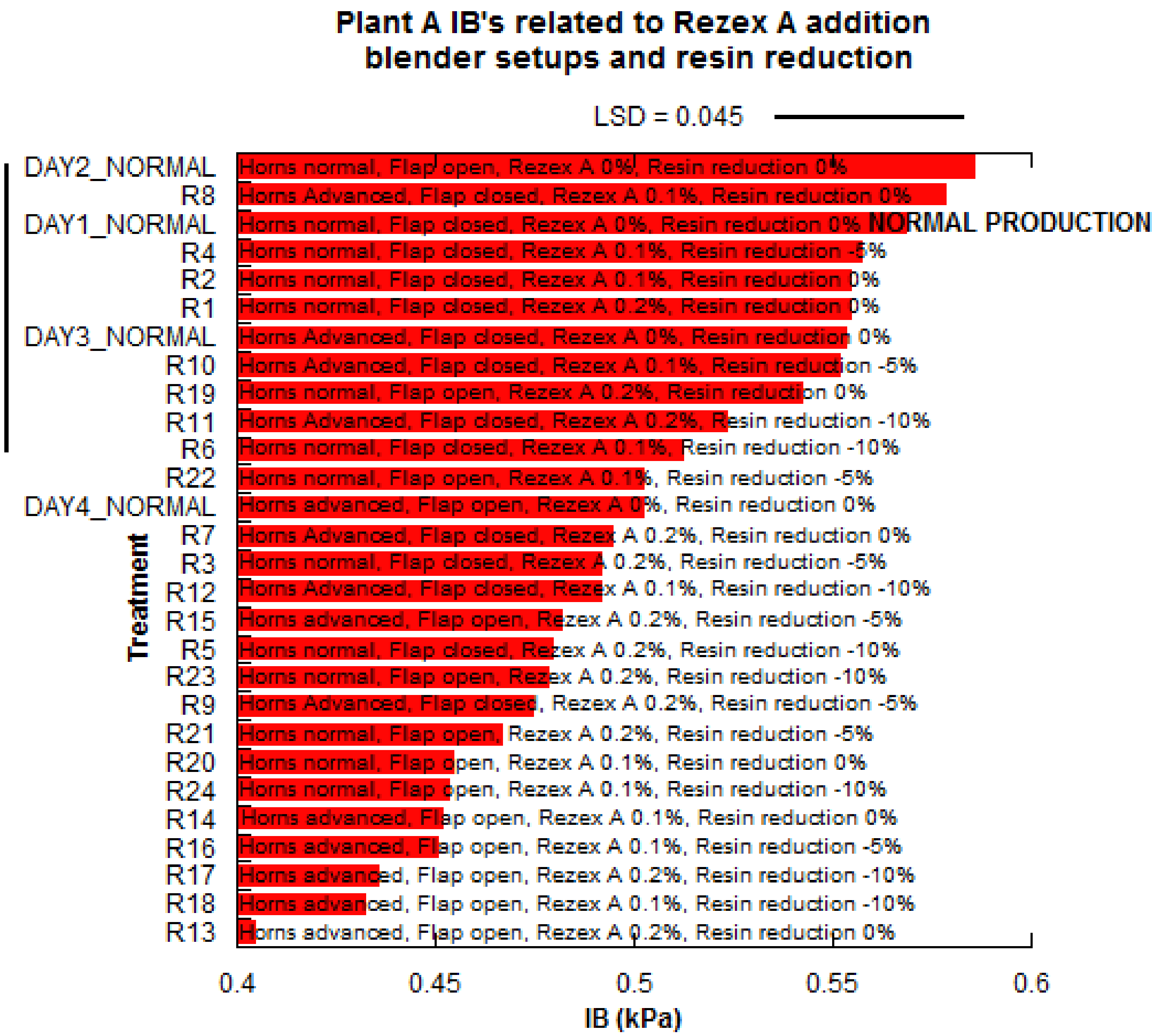

Figure 2, Plant A IB values related to addition of Rezex A and various blender setups and reduced resin loadings

The following treatments for Plant A would achieve up to a 10% resin reduction while making good quality board (Table 7).

Treatment	Horn position	Flap position	Rezex A dose	Resin reduction
R5	Normal	Closed	0.2%	10%
R6	Normal	Closed	0.1%	10%
R12	Advanced	Closed	0.1%	10%
R23	Normal	Open	0.2%	10%

Table 7, Treatments from Plant A that would achieve a 10% resin reduction

The following treatments for Plant A could achieve up to a 5% resin reduction while making good quality board.

Treatment	Horn position	Flap position	Rezex A dose	Resin reduction
R21	Normal	Open	0.2%	5%
R4	Normal	Closed	0.1%	5%
R10	Advanced	Closed	0.1%	5%

Table 8, Treatments for Plant A that would achieve a 5% resin reduction.

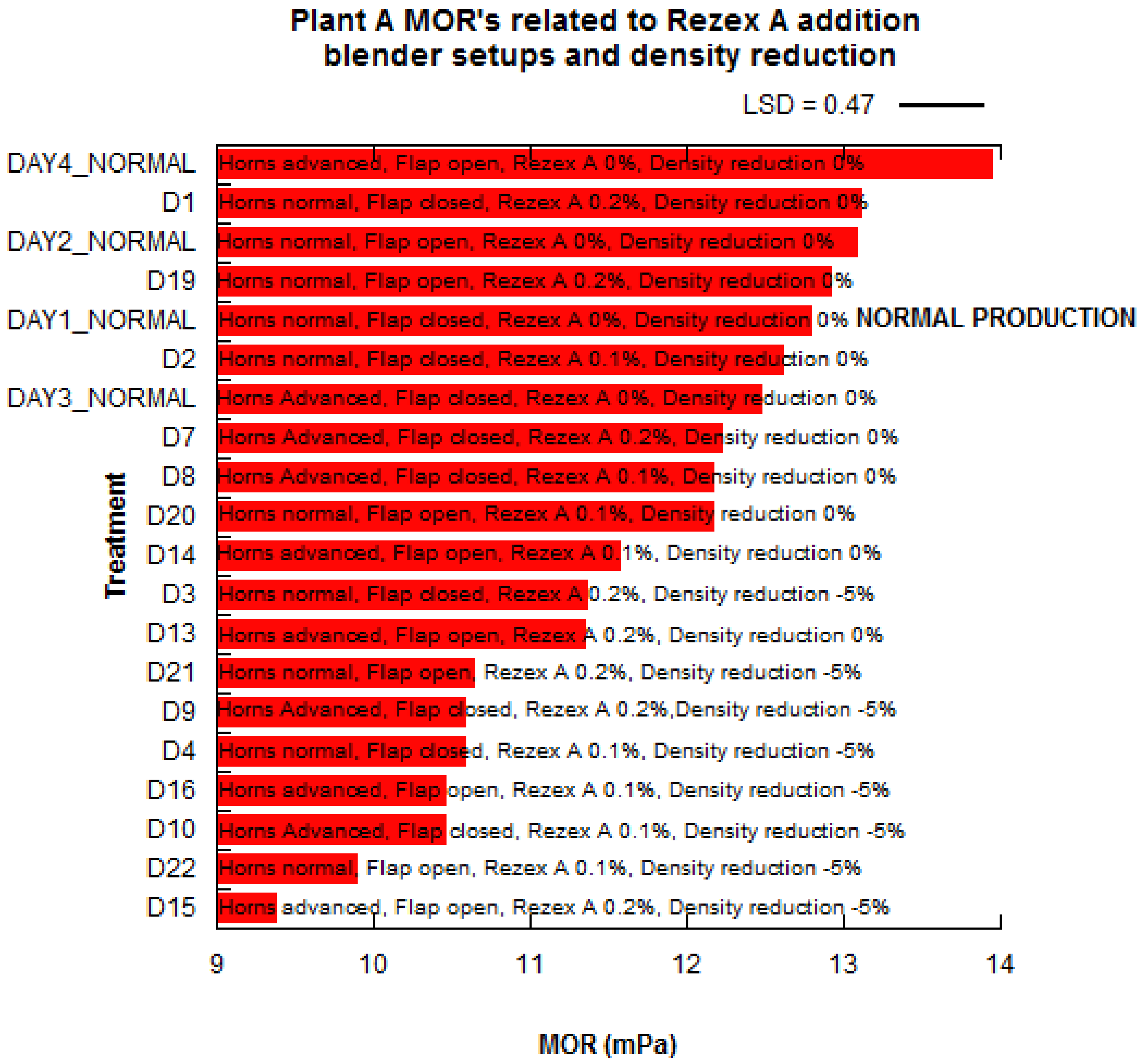

Figure 3, Plant A MOR values related to addition of Rezex A and various blender setups and reduced density.

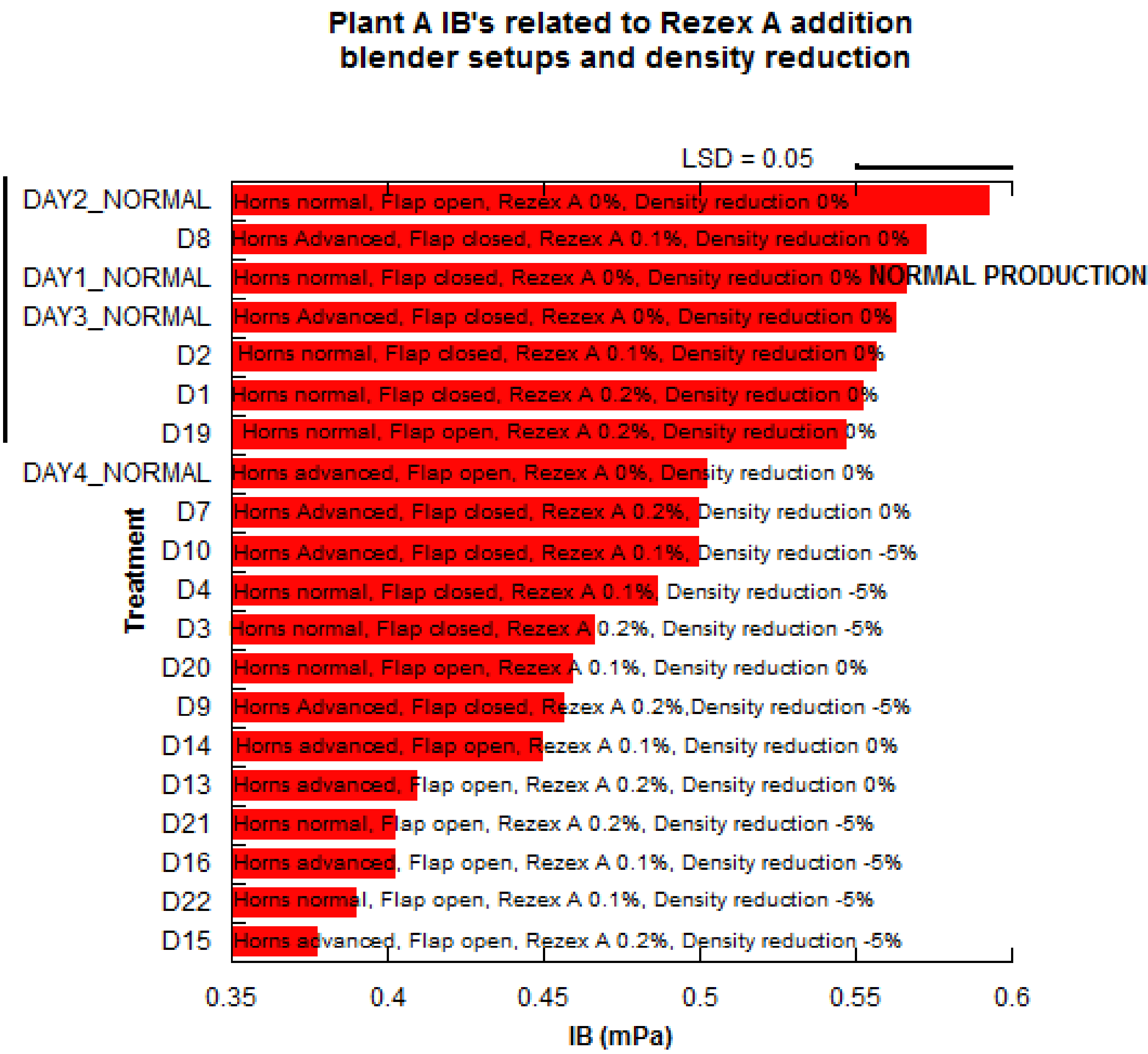

Figure 4, Plant A IB values related to addition of Rezex A and various blender setups and reduced density.

There was no opportunity in plant A to reduce density, the original density being below 650 kgs/m^3.

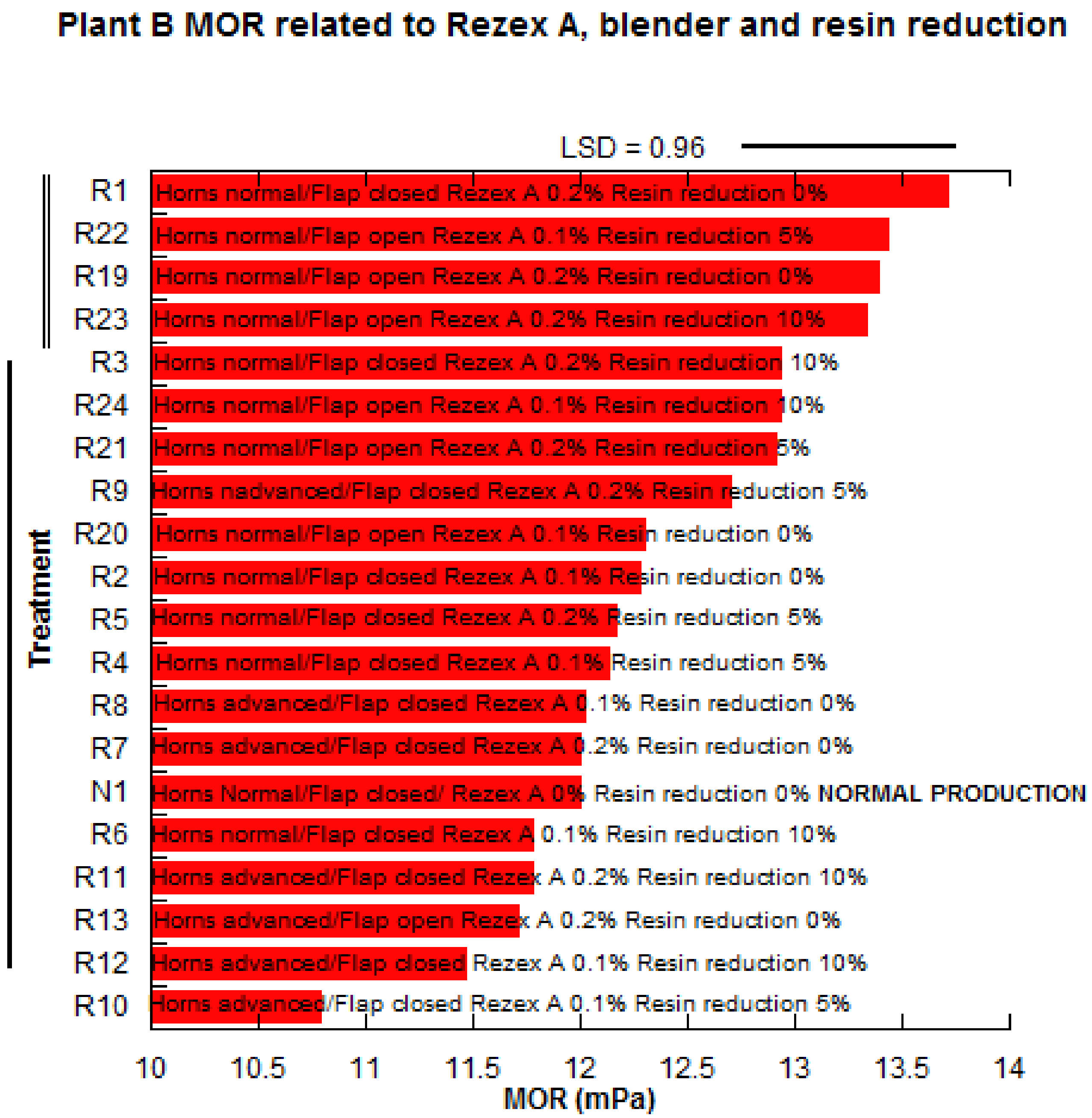

Figure 5, Plant B MOR values related to addition of Rezex A and various blender setups and reduced resin loadings.

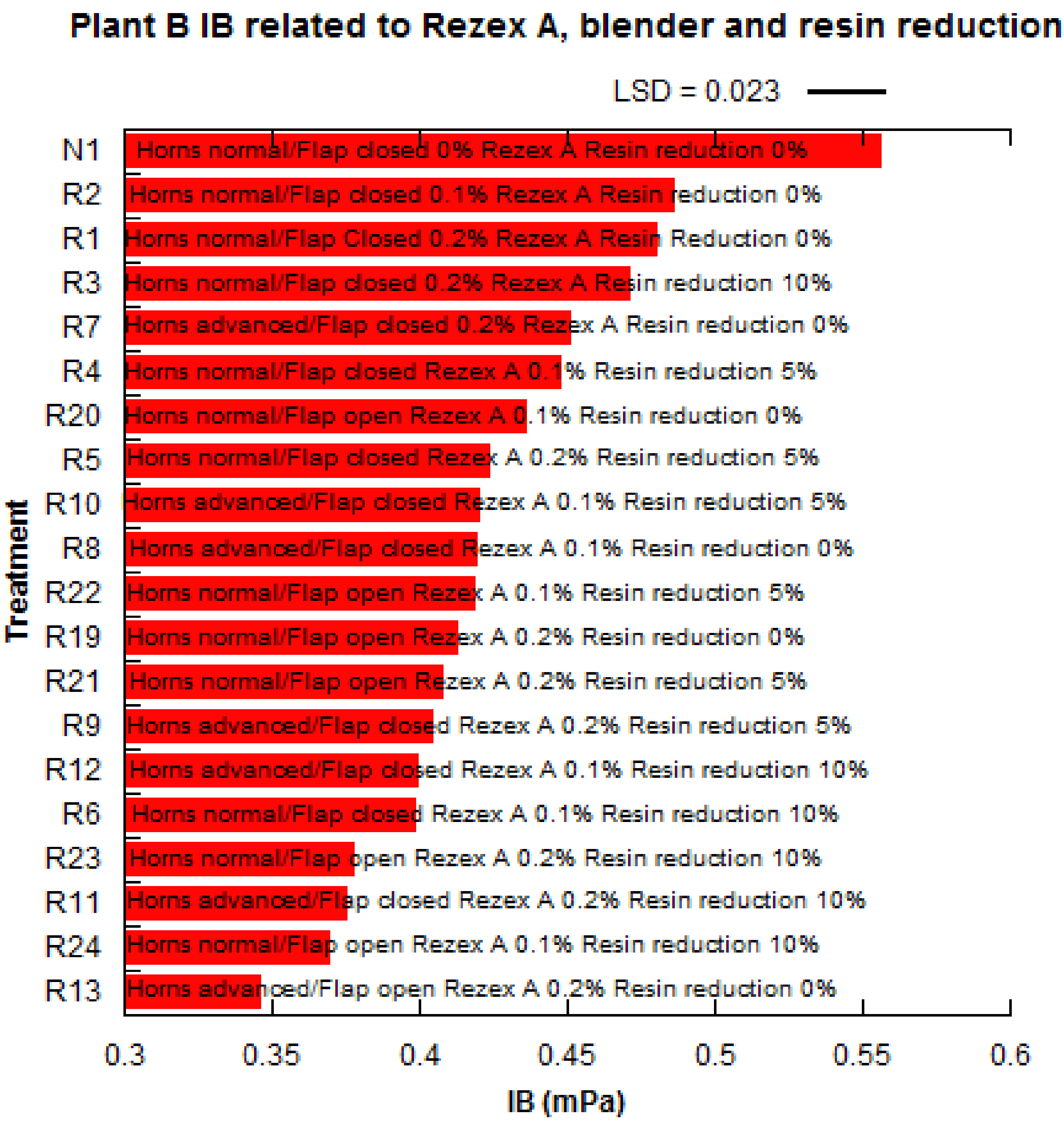

Figure 6, Plant B IB values related to addition of Rezex A and various blender setups and reduced resin loadings.

The following treatments for **Plant B** give adequate IB and MOR values with 10% resin reduction (Table 9).

Treatment	Horn position	Flap position	Rezex A dose (%)	Resin reduction (%)
R5	Normal	Closed	0.2	10
R12	Advanced	Closed	0.1	10
R6	Normal	Closed	0.1	10

Table 9, Treatments for Plant B that result in a 10% resin reduction

The following treatments for **Plant B** gave adequate MOR and IB values with 5% resin reduction (Table 10).

Treatment	Horn position	Flap position	Rezex A dose (%)	Resin reduction (%)
R4	Normal	Closed	0.1	5
R3	Normal	Closed	0.2	5
R10	Advanced	Closed	0.1	5
R22	Normal	Open	0.1	5
R21	Normal	Open	0.2	5
R9	Advanced	Closed	0.2	5

Table 10, Treatments for Plant B that result in a 5% resin reduction.

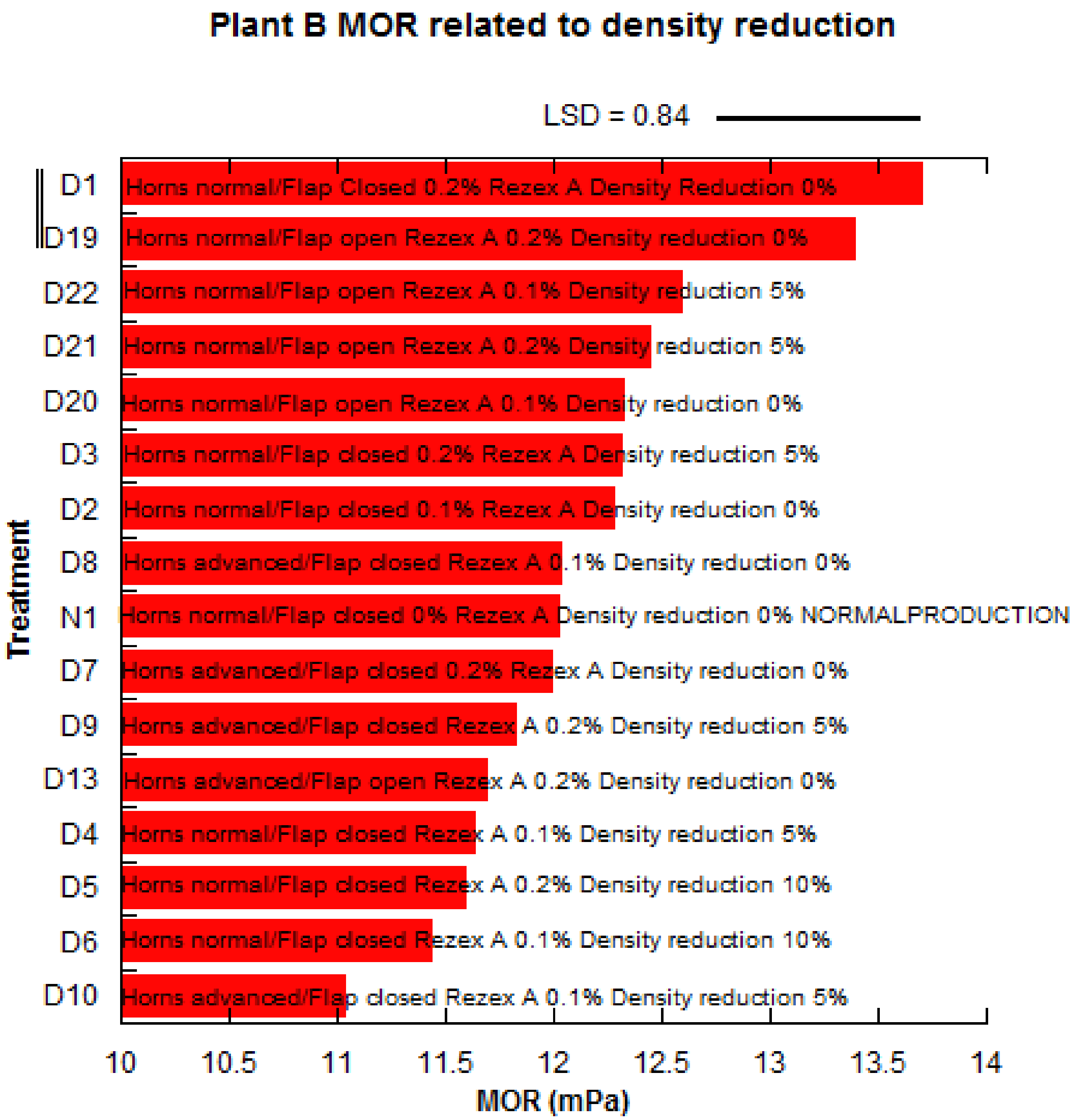

Figure 7, Plant B MOR values related to addition of Rezex A and various blender setups and reduced density.

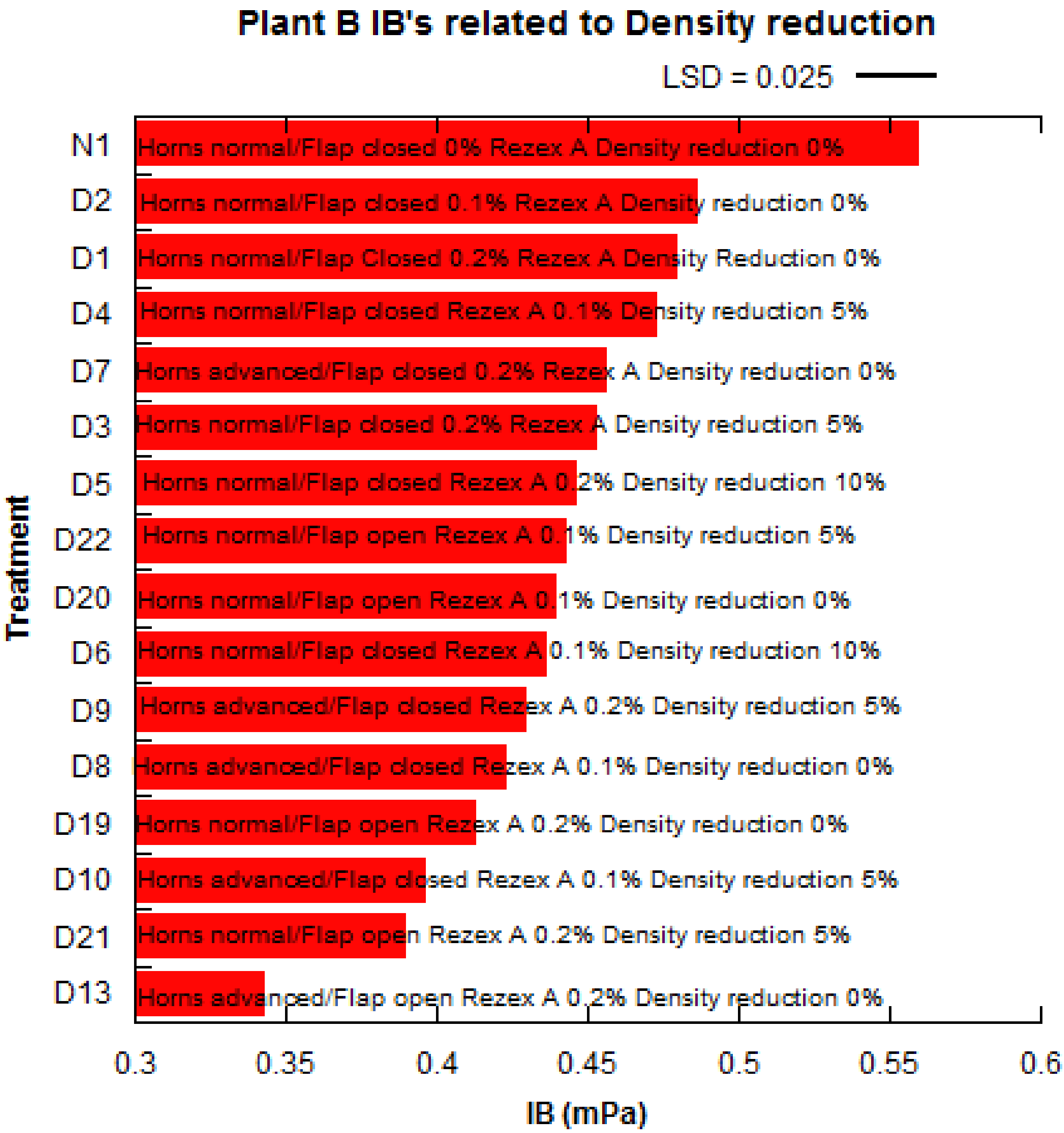

Figure 8, Plant B IB values related to addition of Rezex A and various blender setups and reduced density.

The following treatments for **Plant B** gave density reductions with adequate IB and MOR values (Table 11).

Treatment	Horn position	Flap position	Rezex A dose	Density reduction
D3	Normal	Closed	0.2%	5%
D4	Normal	Closed	0.1%	5%
D5	Normal	Closed	0.2%	10%

Table 11, Treatments for Plant B that can result in a 5% density reduction.

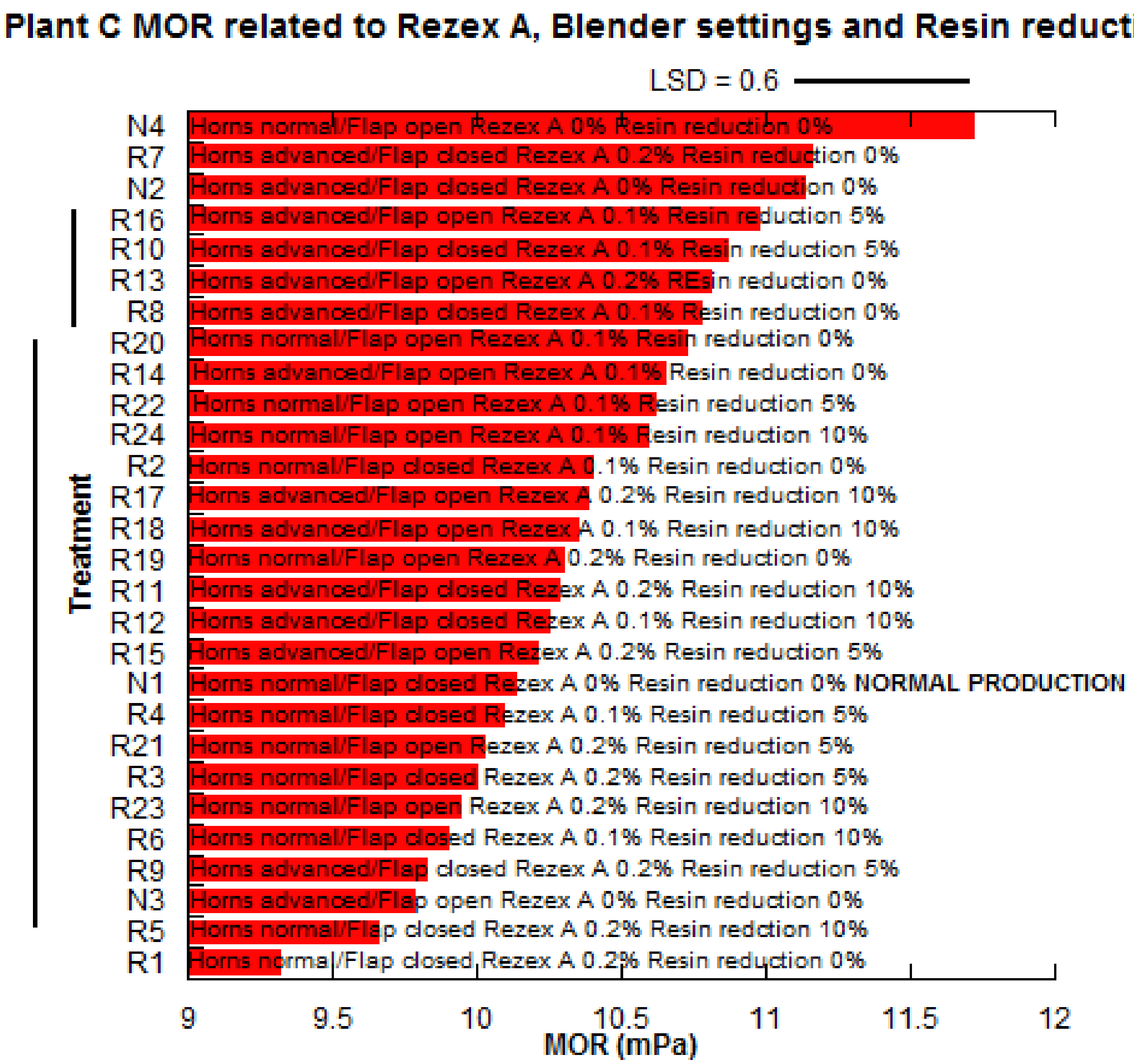

Figure 9, Plant C MOR values related to addition of Rezex A and various blender setups and reduced resin loadings.

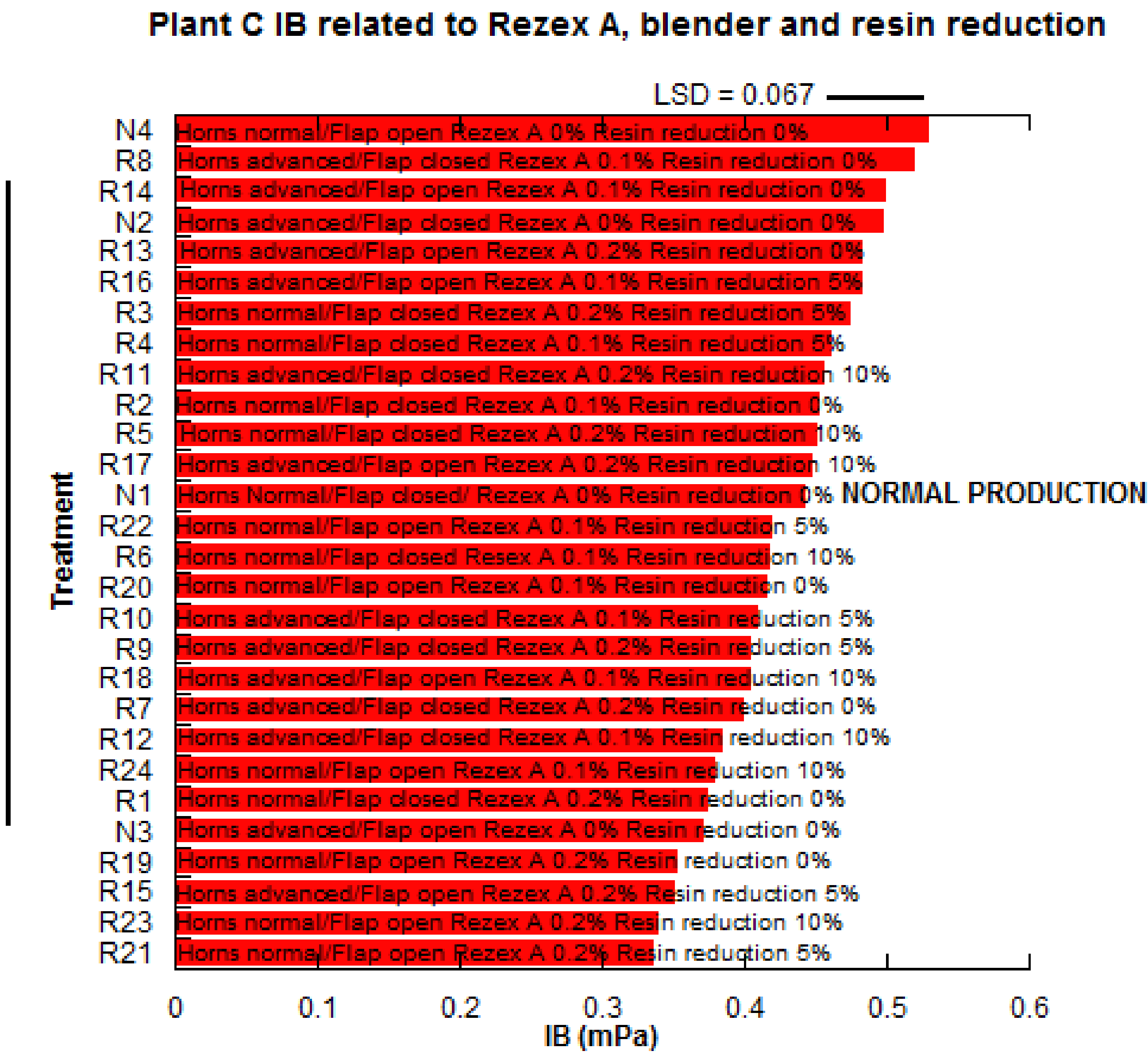

Figure 10, Plant B IB values related to addition of Rezex A and various blender setups and reduced resin loadings.

The following treatments for **Plant C** achieve 10% resin reductions and achieve acceptable IB and MOR values in that they are not significantly different than Normal Production (Table 12).

Treatment	Horn position	Flap position	Rezex A dose %	Resin reduction %
R5	Normal	Closed	0.2	10
R6	Normal	Closed	0.1	10
R11	Advanced	Closed	0.2	10
R12	Advanced	Closed	0.1	10
R17	Advanced	Open	0.2	10
R18	Advanced	Open	0.1	10
R24	Normal	Open	0.1	10

Table 12, Treatments for Plant B that result in a 10% resin reduction.

The following treatments for **Plant C** achieve 5% resin reductions and achieve acceptable IB and MOR values in that they are not significantly different than Normal Production (Table 13).

Treatment	Horn position	Flap position	Rezex A dose %	Resin reduction %
R3	Normal	Closed	0.2	5
R4	Normal	Closed	0.1	5
R9	Advanced	Closed	0.2	5
R10	Advanced	Closed	0.1	5
R16	Advanced	Open	0.1	5
R22	Normal	Open	0.1	5

Table 13, Treatments for Plant C that result in a 5% resin reduction.

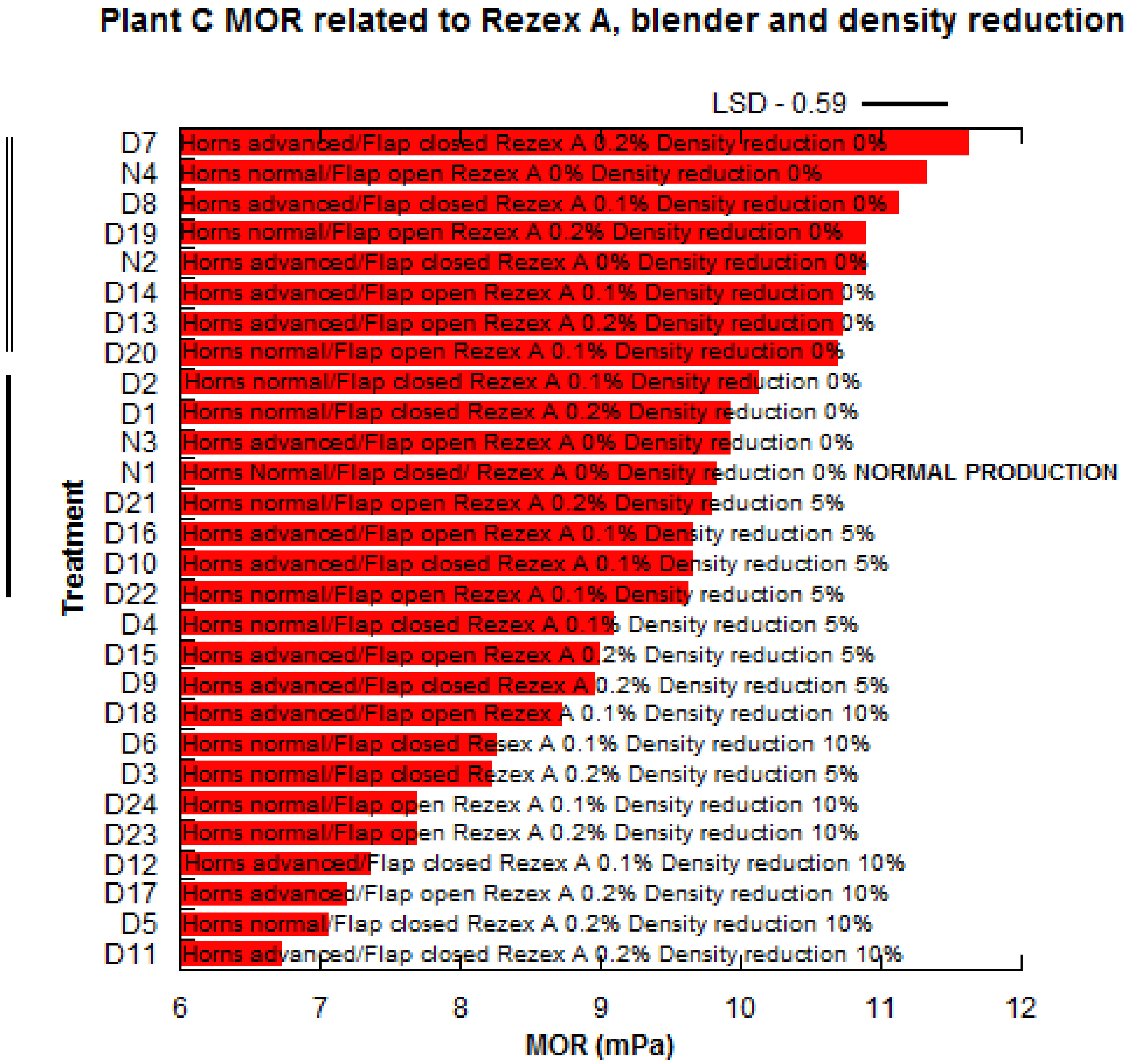

Figure 11, Plant C MOR values related to addition of Rezex A and various blender setups and reduced density.

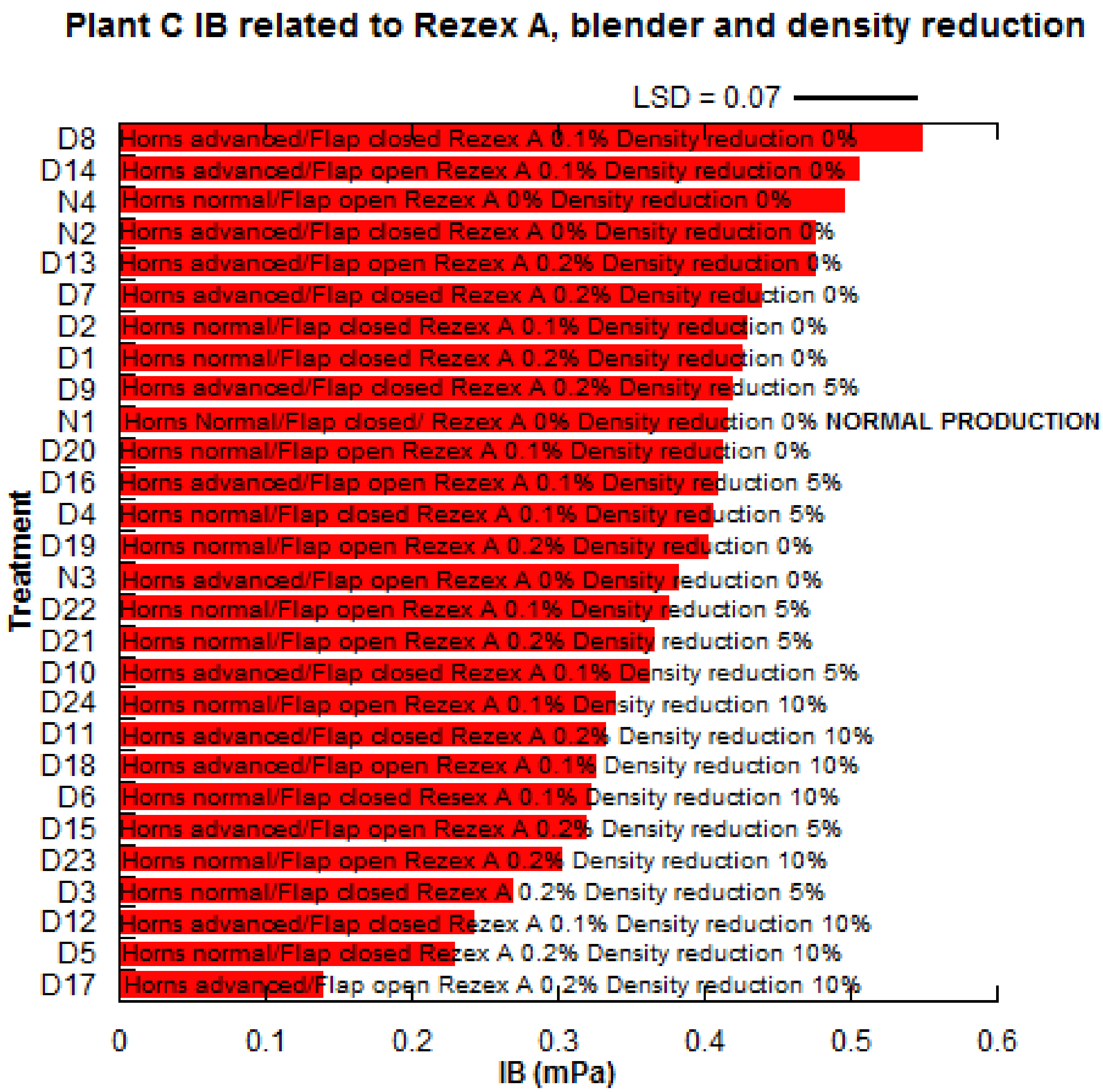

Figure 12, Plant C IB values related to addition of Rezex A and various blender setups and reduced density.

The following treatments for **Plant C** achieve density savings as well as acceptable IB and MOR values.

Treatment	Horn position	Flap position	Rezex A %	Density reduction %
D10	Advanced	Closed	0.1	5
D16	Advanced	Open	0.1	5
D21	Normal	Open	0.2	5
D22	Normal	Open	0.1	5

Table 14, Treatments for Plant C that result in a 5% density reduction.

Plant	**Treatment**	**Horn position**	**Flap position**	**Rezex A dose**	**Resin reduction**
A	**R12**	**Advanced**	**Closed**	**0.10%**	**10%**
B	**R12**	**Advanced**	**Closed**	**0.10%**	**10%**
C	**R12**	**Advanced**	**Closed**	**0.10%**	**10%**
A	***R10***	***Advanced***	***Closed***	***0.10%***	***5%***
B	***R10***	***Advanced***	***Closed***	***0.10%***	***5%***
C	***R10***	***Advanced***	***Closed***	***0.10%***	***5%***
A	**R6**	**Normal**	**Closed**	**0.10%**	**10%**
B	**R6**	**Normal**	**Closed**	**0.10%**	**10%**
C	**R6**	**Normal**	**Closed**	**0.10%**	**10%**
A	**R5**	**Normal**	**Closed**	**0.20%**	**10%**
B	**R5**	**Normal**	**Closed**	**0.20%**	**10%**
C	**R5**	**Normal**	**Closed**	**0.20%**	**10%**
A	***R4***	***Normal***	***Closed***	***0.10%***	***5%***
B	***R4***	***Normal***	***Closed***	***0.10%***	***5%***
C	***R4***	***Normal***	***Closed***	***0.10%***	***5%***

Table 15, A summary of identical results from all trials and from all plants.