How much methanol should you use?

The *stoichiometric* quantity of methanol is the amount needed to convert triclycerides (fats and oils) into esters (biodiesel) -- the "methyl" portion of methyl esters.

You also need an *excess* of methanol to push the conversion process towards completion -- without the excess the process runs out (reaches equilibrium) before all the triglycerides are converted to esters, resulting in poor fuel that doesn't combust well and can be corrosive.

The excess methanol acts more like a catalyst: it encourages the process but does not become a part of the final product and can be recovered afterwards.

Stoichiometric quantity

The stoichiometric quantity is usually said to be 12.5% methanol by volume -- that is, 125 millilitres of methanol per litre of oil. Some people put it at 13%, or 13.5%, or even as low as 8%.

In fact it depends on the amounts of the various fatty acids in the oil, and varies from one oil to another. Biofuel mailing list member Christian Lenoir figured it out, and here are the results. Christian provided the average proportions of the different fatty acids in each of the more common fats and oils, calculated their total molecular weights, and from this was able to calculate the stoichiometric amount of methanol required to convert them. The amount varies from 11.3% for rapeseed oil (canola) to 16.3% for coconut oil.

These figures are averages -- fatty acid quantities vary somewhat when oil crops are grown in different conditions in different parts of the world. But they're close enough for our purposes, and a lot more accurate than the general figure of 12.5%.

If you have an analysis of the fatty acid content of your oil, you can calculate the correct stoichiometric ratio from the figures provided in these tables.

Fats and oils	**Fatty acids %**							
	C4:0 Butyric	C6:0 Caproic	C8:0 Caprylic	C10:0 Capric	C12:0 Lauric	C14:0 Myristic	C16:0 Palmitic	C16:1 Palmitoleic
Molecular wt.	*88*	*116*	*144*	*172*	*200*	*228*	*256*	*254*
Tallow	-	-	-	-	0.2	3	27	2
Lard	-	-	-	-	-	1	26	2

Butter	3.5	1.5	-	2.5	3	11	30	3.5
Coconut	-	-	8	8	48	16	8.5	-
Palm kernel	-	-	3	5	48.5	17	7.5	0.5
Palm	-	-	-	-	-	3.5	39.5	-
Safflower	-	-	-	-	-	-	5.2	-
Peanut	-	-	-	-	-	0.5	7	1.5
Cottonseed	-	-	-	-	-	1.5	19	-
Maize	-	-	-	-	-	1	9	1.5
Olive	-	-	-	-	0.5	1	13	2
Sunflower	-	-	-	-	-	-	6	-
Soy	-	-	-	-	-	0.3	7.8	0.4
Rapeseed/Canola	-	-	-	-	-	-	3.5	0.2
Mustard	-	-	-	-	-	-	3	-
Cod liver oil	-	-	-	-	-	4	10	14.5
Linseed	-	-	-	-	-	0.2	6	-
Tung	-	-	-	-	-	-	-	-

Fats and oils (continued)	**Fatty acids %**						
	C18:0 Stearic	C18:1 Oleic	C18:2 Linoleic	C18:3 Linolenic	C20:0 C22:0 Arachydic - Behenic & others	Mono-unsaturated acids <C16:1	C20:1 C22:1 Arachidonic - Erucic & others
Molecular wt.	*284*	*282*	*280*	*278*	*326*	*226*	*324*
Tallow	24.1	40.7	2	-	0.7	-	0.3
Lard	13	45.2	10.3	-	-	-	2.5
Butter	12	26	3	-	1.65	1.5	0.85
Coconut	2.5	6.5	2	-	-	-	0.5
Palm kernel	2	14	1	-	1.5	-	-
Palm	3.5	46	7.5	-	-	-	-
Safflower	2.2	76.4	16.2	-	-	-	-
Peanut	4.5	52	27	-	7.5	-	-
Cottonseed	2	31	44	-	-	-	2.5
Maize	2.5	40	45	-	-	-	1
Olive	2	68	12	-	0.5	-	1

Sunflower	4.2	18.7	69.4	0.3	1.4	-	-
Soy	2.5	26	51	5	7	-	-
Rapeseed/Canola	2	13.5	17	7.5	0.9	-	56.3
Mustard	1.5	39.5	12	8	-	-	36
Cod liver oil	0.5	28	-	-	-	1	42
Linseed	5	17.3	16	55	0.5	-	-
Tung	-	8	12	80	-	-	-

Oils and fats	**Total molecular weight**	**Density**	**Density @ 50ºC**	**Volume oil (ml)**	**Volume methanol (ml)**	**Stoich. ratio methanol : oil %**
Tallow	858.54	0.895	0.88	981.18	121.52	12.4
Lard	863.73	0.92*	0.9*	959.7*	121.52	12.7
Butter	797.64	0.91	0.89	896.73	121.52	13.6
Coconut	674.51	0.926	0.91	744.57	121.52	16.3
Palm kernel	704	0.912	0.89	789.33	121.52	15.4
Palm	847.28	0.923	0.9	938.29	121.52	13
Safflower	879.1	0.927	0.91	966.44	121.52	12.6
Peanut	885.02	0.919	0.9	984.45	121.52	12.3
Cottonseed	867.38	0.918	0.9	963.76	121.52	12.6
Maize	872.81	0.923	0.9	966.57	121.52	12.6
Olive	870.65	0.923	0.9	964.17	121.52	12.6
Sunflower	877.22	0.925	0.91	969.3	121.52	12.5
Soy	882.82	0.925	0.91	975.5	121.52	12.5
Rapeseed/Canola	959.04	0.914	0.89	1072.75	121.52	11.3
Mustard	925.43	0.916	0.9	1032.85	121.52	11.8
Cod liver oil	908.81	0.929	0.91	1000.34	121.52	12.1
Linseed	872.4	0.934	0.91	954.48	121.52	12.7
Tung	873.68	0.944	0.92	945.54	121.52	12.9
* Approximate						

Excess

Further arguments rage over how much excess is needed, with figures quoted claiming that *this* much will achieve 98% conversion but *that* much only 95% or less.

It depends on several different factors: the type of oil, its condition, the type, size and shape of the processor, the type and duration of agitation, the temperature of the process -- and it doesn't make much sense anyway if the stoichiometric ratio is wrong in the first place.

However, excess is usually between 60% and 100% of the stoichiometric amount. So if the stoichiometric ratio of the oil you're using is 12.5%, that is 125 ml of methanol per litre of oil, the excess would range between 75 ml and 125 ml, for a total amount of methanol of 200-250 ml per litre of oil.

Oils with higher stoichiometric ratios seem to need higher excesses. So, for fresh (virgin, uncooked) soy or canola, you can try 60%, though 67% or more would be better. For palm kernel or coconut, closer to 100% excess would be better. For tallow and lard, use higher excesses.

For used oil, WVO -- waste vegetable oil, as it's called, though it often contains animal fats from the cooking, use 67% minimum excess. For heavily used oils with high titration levels, use higher excesses, up to 100%.

If you don't know what kind of oil your WVO is, try using 25% methanol -- 250 ml methanol to 1 litre of oil. If you've taken care with the titration, used accurate measurements and followed the instructions carefully, you should get a good, clean "split", with esters on top and the glycerine and free fatty acids cleanly separated at the bottom. If you have trouble washing it, with a lot of frothing, that could be because the process didn't go far enough and unconverted material is forming emulsions -- try using more methanol next time. If everything works well, try using less methanol. You'll soon figure out what's best for you.

With the "**Foolproof**" acid-base two-stage method, don't worry about it, just follow the instructions.

Ethyl esters

The same principles apply for making ethyl esters instead of methyl esters, using ethanol rather than methanol -- with some differences. Use 1.4 times more ethanol than methanol. It won't work if there's any water in the ethanol or the oil. It works much better with some methanol added, up to 3:1 ethanol:methanol. Virgin oil is better -- with waste oil (WVO) it won't work with FFA content much more than 1ml by titration. Experiment -- there's more information here: **Ethyl-esters biodiesel**. Please let us know your results.

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