

# Technology and Application for Increasing Protein Utilization Efficiency of Pig Feed



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# Digestibility of ingredients' protein in common pig feed

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# Crude protein intestinal digestibility of feed ingredients in pigs



Ingredients	CP %	Ingredients	CP %	Ingredients	CP %
Northeastern China corn	76.4	Rice bran	66.2	Wheat bran	76.1
Demeiya Corn	83.0	Wheat	83.6	DDGS(Distiller's Dried Grains with Solubles)	68.3
Aged corn and brown rice mixtures	86.8	Corn	73.9	Corn germ meal	55.8
Rice kernel	77.2	Soybean meal 1	96.4	Flour	81.4
Wheat	87.6	Soybean meal 2	88.9	Soybean meal	85.4

# Crude protein intestinal digestibility of feed ingredients in pigs



Ingredients	CP %	Ingredients	CP %	Ingredients	CP %
Corn	77.5	Corn 1	77.7	Corn	76.7
Brown rice	80.3	Corn 2	79.6	Soybean meal 1	88.7
Rice kernel 1	78.7	Wheat middlings 1	87.0	Soybean meal 2	93.0
Rice kernel 2	71.5	Wheat middlings 2	96.7	Corn germ meal	82.6
Rice bran 1	67.3	Wheat bran 1	82.6	DDGS 1	88.6
Rice bran 2	92.2	Wheat bran 2	74.4	DDGS 2	78.8

# Standardized ileal digestibility of crude protein and lysine in pigs by feed ingredients



Ingredients	SID CP %	SID Lys	Ingredients	SID CP %	SID Lys
Corn	88	69	Corn germ meal	64	66
Soybean meal	84	89	Rice bran	75	80
Wheat	95	88	Rice bran meal	76	73
Wheat bran	72	80	Cottonseed meal	79	63
Wheat middlings	92	87	Rapeseed meal	65	68
Corn DDGS	73	65	Peanut meal	83	75

# Digestibility of nutrients in piglet feed



Item	Diet 1	Diet 2	Diet 3
<b>Earlier Stage (3 weeks post weaning, weight 13 kg)</b>			
<b>CP %</b>	<b>69.5<sup>ab</sup></b>	<b>62.9<sup>b</sup></b>	<b>67.6<sup>ab</sup></b>
<b>GE %</b>	<b>78.3<sup>ab</sup></b>	<b>74.5<sup>b</sup></b>	<b>77.2<sup>ab</sup></b>
<b>DM %</b>	<b>77.4<sup>ab</sup></b>	<b>73.7<sup>a</sup></b>	<b>75.9<sup>ab</sup></b>
<b>OM %</b>	<b>81.2<sup>ab</sup></b>	<b>78.1<sup>b</sup></b>	<b>80.0<sup>ab</sup></b>
<b>Later Stage (5 weeks post weaning, weight 21 kg)</b>			
<b>CP %</b>	<b>70.6</b>	<b>71.6</b>	<b>71.1</b>
<b>GE %</b>	<b>78.7</b>	<b>79.5</b>	<b>78.1</b>
<b>DM %</b>	<b>78.7</b>	<b>79.5</b>	<b>78.2</b>
<b>OM %</b>	<b>82.1</b>	<b>82.7</b>	<b>81.2</b>

Compared to the later stage, crude protein digestibility in the earlier stage is 1.1-8.7 percents lower, on average lower by 4.4 percents

# Digestibility of nutrients in growing and fattening pig feed



Item	Corn DDGS + Wheat bran		Corn DDGS		SEM	Diet	P-value	
	-	+xylanase	-	+xylanase			Xylanase	Interaction
<b>Day 30</b>								
Dry matter%	83.6	84.5	84.2	85.6	0.68	0.68	0.28	0.79
Total energy%	83.4	84.7	84.5	86.3	0.71	0.84	0.18	0.65
<b>Crude protein%</b>	<b>78.3</b>	<b>79.1</b>	<b>78.8</b>	<b>79.4</b>	<b>0.62</b>	<b>0.77</b>	<b>0.57</b>	<b>0.88</b>
<b>Day 65</b>								
Dry matter %	82.9	84.7	82.4	85.1	0.63	0.73	0.08	0.66
Total energy %	81.8	83.8	82.0	85.4	0.59	0.24	0.03	0.39
<b>Crude protein%</b>	<b>77.3</b>	<b>78.9</b>	<b>77.1</b>	<b>78.9</b>	<b>0.60</b>	<b>0.87</b>	<b>0.04</b>	<b>0.93</b>
<b>Day 95</b>								
Dry matter %	81.1	83.8	81.2	84.1	0.61	0.48	< 0.01	0.88
Total energy %	80.6	83.1	80.5	82.9	0.64	0.64	< 0.01	0.74
<b>Crude protein %</b>	<b>78.8</b>	<b>80.3</b>	<b>77.6</b>	<b>79.8</b>	<b>0.67</b>	<b>0.75</b>	<b>0.02</b>	<b>0.91</b>



# Digestibility of crude protein in pig feed at different physiological stages



Item	Diet1		SEM	P-value	Diet2		SEM	P-value	Diet3		SEM	P-value
	Sow	Fattening pig			Sow	Fattening pig			Sow	Fattening pig		
Total energy %	0.89	0.87	0.01	< 0.05	0.89	0.88	< 0.01	< 0.05	0.81	0.76	0.01	< 0.05
Organic matter %	0.92	0.89	0.38	< 0.05	0.92	0.90	0.32	< 0.05	0.84	0.80	0.46	< 0.05
<b>Crude protein%</b>	<b>0.89</b>	<b>0.85</b>	<b>0.53</b>	<b>&lt; 0.05</b>	<b>0.87</b>	<b>0.85</b>	<b>0.81</b>	<b>&lt; 0.05</b>	<b>0.84</b>	<b>0.75</b>	<b>0.65</b>	<b>&lt; 0.05</b>
Neutral detergent fiber(NDF)%	0.66	0.64	1.96	< 0.05	0.62	0.61	1.70	0.22	0.56	0.50	0.94	< 0.05
Acid detergent fiber(ADF)%	0.78	0.70	1.95	< 0.05	0.74	0.63	1.56	< 0.05	0.55	0.36	1.32	< 0.05



# Ways to increase protein utilization efficiency in feed

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# Factors affecting protein digestibility of feed ingredients



## ➤ Animal

- Breed
- Weight stage
- Physiological stage
- Health condition
- Etc.

## ➤ Feed and ingredients

- Feed and ingredient quality (**composition, storage**)
- Feed and raw material processing technology
- Formulation technology
- Use of enzyme
- Use of other supplements
- Etc.

# Effect of pig weight stage on protein digestibility of feed ingredients



Weight stages	15kg	30kg	60kg	100kg
Corn	81	86	87	92
Wheat	81	86	87	92
Barley	72	73	78	82
Sorghum	59	60	67	70
Soybean meal	-	90	92	95
Rapeseed meal	-	75	79	86
Cottonseed meal	-	81	84	89
Wheat bran	-	75	77	96
Corn DDGS	-	88	89	92

**Unit: %**

# Effect of grinding particle size on the digestibility of nutrients in feed containing corn DDGS



Item	Growing pig			Fattening pig			<i>P</i> value	
Particle size	Hammer 450	Roller 450	Untreated 650	Hammer 450	Roller 450	Untreated 650	Ingredient treatment	Growing stage
DM %	79.8 <sup>ab</sup>	79.2 <sup>bc</sup>	77.9 <sup>c</sup>	81.0 <sup>a</sup>	80.7 <sup>ab</sup>	77.8 <sup>c</sup>	< 0.001	0.091
GE %	78.2 <sup>bc</sup>	77.7 <sup>cd</sup>	76.4 <sup>cd</sup>	80.1 <sup>a</sup>	79.9 <sup>ab</sup>	76.0 <sup>d</sup>	< 0.001	0.026
CP %	77.5 <sup>c</sup>	77.0 <sup>c</sup>	76.2 <sup>c</sup>	81.5 <sup>ab</sup>	81.7 <sup>a</sup>	78.8 <sup>bc</sup>	0.090	< 0.001
NDF %	46.6	50.2	44.9	48.5	45.1	44.7	0.477	0.335

# Effect of extrusion-expansion on the effective energy and nutrient digestibility of grains



Item	Energy kcal/kg			Apparent intestinal digestibility%						
	Digestible energy	Metabolizable energy	DE difference before and after expansion	Total energy	Dry matter	Organic matter	Crude protein	Crude fat	NDF	ADF
Broken rice	-	4092	81	95.30	96.56	97.26	85.23	59.31	77.12	-
	+	4173		4120	95.66	96.82	97.55	87.78	30.30	75.90
Wheat	-	3812	163	84.85	89.59	91.28	87.82	35.11	60.31	42.24
	+	3975		3898	87.88	86.39	88.70	85.28	25.06	61.33
Barley	-	3587	-60	81.10	83.23	83.60	69.60	6.66	57.14	21.45
	+	3528		3466	80.97	83.38	83.97	74.41	4.34	60.12
Sorghum	-	3915	84	86.85	88.95	89.82	71.89	30.69	64.69	49.71
	+	3999		3953	88.94	89.49	91.01	80.53	27.78	66.14

# Effect of extrusion-expansion on nutrient digestibility of high-oil ingredients



Item	Expansion or not	DE kcal/kg	ME kcal/kg	GE %	DM %	OM %	CP %	AEE %	NDF %	ADF%
Full fat rice bran	-	3291	3258	70.50	59.66	63.78	53.83	61.36	26.10	18.73
	+	3666	3537	79.14	64.90	69.43	60.99	79.15	29.02	15.42
Corn DDGS	-	3325	3131	68.60	61.88	63.04	69.55	72.43	43.99	45.74
	+	3929	3750	78.41	68.20	69.19	76.08	76.09	53.99	48.06
Wheat germ	-	3920	3633	89.65	80.04	82.73	87.03	75.03	73.39	57.44
	+	3951	3662	91.15	79.84	82.87	85.33	83.11	55.54	24.37

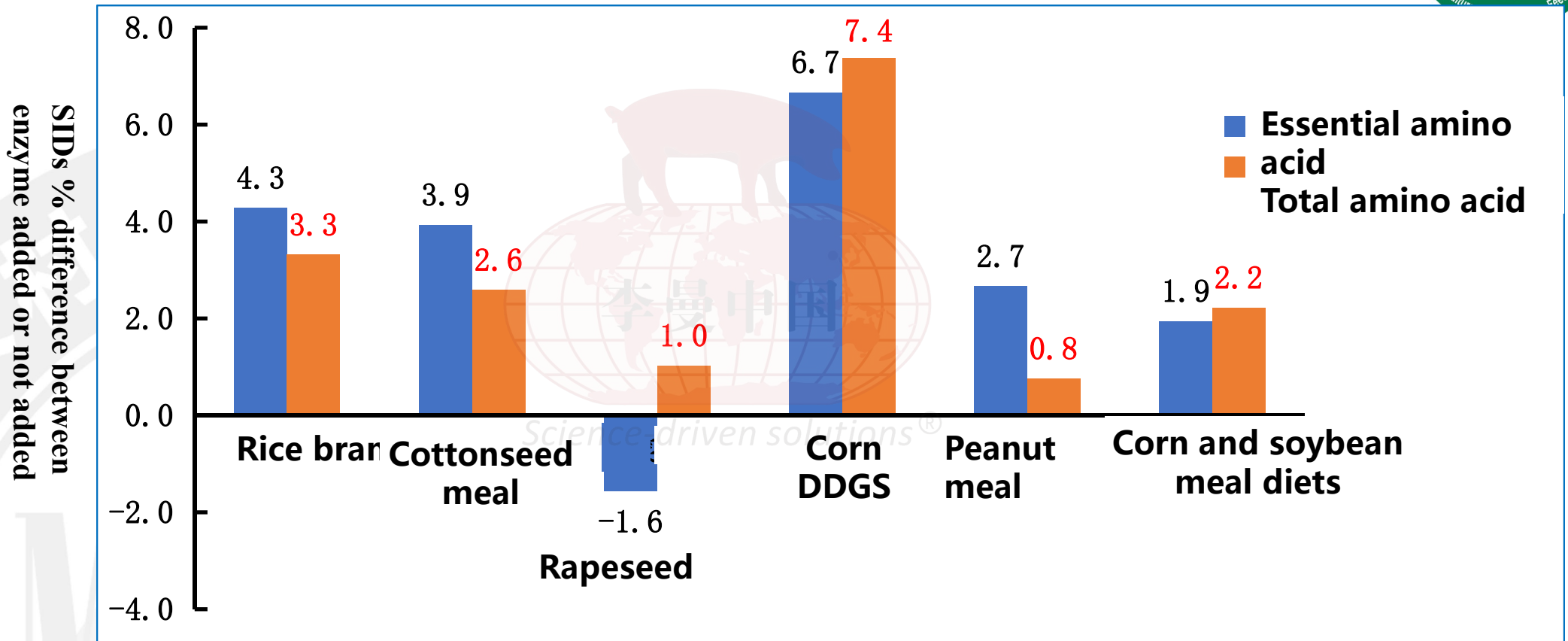
# Effect of extrusion-expansion on standardized ileal digestibility of amino acids from high-oil ingredients



Item	Expansion or not	CP %	Arg %	His %	Ile %	Leu %	Lys %	Met %	Phe %	Thr %	Trp %	Val %
Full fat rice bran	-	67.82	86.87	82.13	79.32	82.63	74.66	73.20	75.49	82.21	76.71	81.95
	+	72.61	87.51	91.37	92.20	85.74	89.58	82.09	93.03	87.55	81.75	93.52
Corn DDGS	-	75.31	77.23	81.18	88.22	86.13	70.36	85.04	86.09	82.33	74.69	83.33
	+	76.41	84.41	83.70	92.00	86.37	66.13	87.05	88.88	82.18	68.21	84.90
Wheat germ	-	86.39	88.09	84.05	79.88	79.56	78.49	85.15	81.71	74.69	81.18	78.66
	+	91.55	91.13	86.35	85.38	85.27	84.46	88.95	85.36	86.92	84.03	85.26



# Effect of alkaline protease on standardized ileal digestibility of amino acids in feed ingredients



**The improvement of nutritional value should be different when the same enzyme for different raw materials.**

# Effect of different enzyme preparations on the nutrient digestibility in piglet feedstuff



Diet	Total energy %	Dry energy%	Crude fat %	Crude protein %	NDF %	ADF %	Organism%
Basic diet	83.83	83.58	74.92	79.90	46.76	31.21	85.64
Enzyme A diet	85.49	85.79	77.25	81.71	37.98	42.52	87.66
Enzyme B diet	84.23	84.17	76.37	80.42	45.86	38.78	86.11
Enzyme C diet	84.79	84.69	78.50	80.46 <sup>®</sup>	47.13	41.00	86.69
Enzyme D diet	83.36	83.15	75.35	78.78	46.50	33.64	85.36
SEM	0.40	0.41	0.71	0.52	1.71	2.18	0.38
<i>P</i> value	0.47	0.28	0.55	0.51	0.40	0.42	0.31



# Ways to increase protein utilization

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# Protein deposition efficiency in pig corn-soybean meal diets



Weight range	Protein digestibility of feed %	Protein utilization of feed %
35-60kg	86.43	62.42
60-80kg	89.50	59.50
80-100kg	91.31	57.68

# Efficiency of protein utilization in different diets for growing pigs



Item	Basic diet	Full fat rice bran diet	Corn germ meal diet	Corn husk feed	Peanut bran diet	Sunflower meal diet
Intake, g/d	42.7	42.2	47.6	45.4	58.3	53.1
Fecal excretion, g/d	4.4	5.4	8.1	5.9	6.2	7.5
Urinal excretion, g/d	12.1	13.7	14.2	16	25.7	18.1
Deposition, g/d	26.2	23.1	25.4	23.5	26.5	27.5
Digestibility %	89.7	87.2	83.0	87.0	89.4	85.9
<b>Utilization %</b>	<b>61.4</b>	<b>54.7</b>	<b>53.4</b>	<b>51.8</b>	<b>45.5</b>	<b>51.8</b>

# Effect of amino acid balance on protein utilization efficiency



Item	Corn	Corn+3AA	Corn+5AA
Intake, g/d	22.6	24.2	24.3
Fecal excretion, g/d	4.7	4.4	4.3
Urinal excretion, g/d	9.0	6.3	5.0
Deposition, g/d	9.4	13.5	14.9
Digestibility %	79.2	81.8	82.3
<b>Deposition ratio%</b>	<b>41.6</b>	<b>55.8</b>	<b>61.3</b>

# Effect of dietary protein level on protein utilization efficiency in growing pigs



Item	High protein	Low protein	SEM	P value
Dietary protein level	<b>21.48</b>	<b>15.54</b>		
Nutrient digestibility, %				
Dry matter	89.20	87.74	0.42	< 0.01
Total energy	88.44	86.57	0.46	< 0.01
<b>Crude energy</b>	<b>90.80</b>	<b>88.82</b>	<b>0.48</b>	<b>&lt; 0.01</b>
Nitrogen balance, g/d				
Nitrogen intake	40.61	30.18	0.50	< 0.01
Fecal nitrogen excretion	3.74	3.37	0.17	0.06
Urinary nitrogen excretion	17.36	9.28	0.36	< 0.01
Total nitrogen excretion	21.10	12.65	0.31	< 0.01
<b>Nitrogen deposition</b>	<b>19.52</b>	<b>17.53</b>	<b>0.68</b>	<b>&lt; 0.01</b>
<b>Nitrogen deposition/ intake, %</b>	<b>48.02</b>	<b>58.05</b>	<b>1.27</b>	<b>&lt; 0.01</b>

# Effect of dietary protein source diversity on protein utilization efficiency in pigs



Item	Basic diet	Rapeseed cake diet		Rapeseed diet		
		1	2	3	4	5
Corn	72.50	58.00	58.00	58.00	58.00	58.00
Soybean meal	25.00	20.00	20.00	20.00	20.00	20.00
Rapeseed cake diet	0.00	19.50	19.50	19.50	19.50	19.50
Dicalcium phosphate	0.90	0.90	0.90	0.90	0.90	0.90
Stone powder	0.75	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Premix feed	0.50	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00	100.00



# Effect of dietary protein source diversity on protein utilization efficiency in pigs



Item	Basic diet	Rapeseed cake		Rapeseed meal		
		1	2	3	4	5
Intake, g/d	39.3	46.9	48.4	50.6	51.3	39.3
Fecal excretion, g/d	5	6.8	6.8	7.4	9.4	5
Urinal excretion, g/d	13.5	22	16.3	17.6	16	13.5
Deposition, g/d	20.7	18.1	25.3	25.6	25.9	20.7
Nitrogen digestibility %	87.3	85.5	86.0	85.4	81.7	87.3
<b>Total nitrogen utilization %</b>	<b>52.7</b>	<b>38.6</b>	<b>52.3</b>	<b>50.6</b>	<b>50.5</b>	<b>52.7</b>
<b>Digestible nitrogen utilization%</b>	<b>60.3</b>	<b>45.1</b>	<b>60.8</b>	<b>59.3</b>	<b>61.8</b>	<b>60.3</b>

# Effect of diverse dietary protein sources on energy balance in pigs



Project	Basic diet	Rapeseed cake		Rapeseed meal			SEM	P value
		1	2	3	4	5		
Energy conversion efficiency, %								
Urinary energy, % DE	2.5 <sup>b</sup>	4.3 <sup>a</sup>	3.6 <sup>ab</sup>	3.7 <sup>ab</sup>	3.9 <sup>ab</sup>	3.4 <sup>ab</sup>	0.4	0.03
Methane, % DE	0.9	0.7	0.8	0.5	0.8	0.7	0.1	0.39
Metabolizable to digestible energy ratio	96.6	95	95.6	95.8	95.3	95.9	0.4	0.10
<b>Net to metabolic energy ratio</b>	<b>77.5</b>	<b>76.6</b>	<b>78.0</b>	<b>75.6</b>	<b>77.1</b>	<b>76.7</b>	<b>0.8</b>	<b>0.15</b>
Energy balance, kJ/kg BW <sup>0.6</sup> /d								
Metabolic energy intake	1,989	1,979	1,951	1,949	1,963	1,934	26	0.63
<b>Total heat production</b>	<b>1,214</b>	<b>1,207</b>	<b>1,235</b>	<b>1,255</b>	<b>1,273</b>	<b>1,222</b>	<b>31</b>	<b>0.53</b>
Energy deposition energy	304	277	373	363	374	381	29	0.07
Fat deposition	471 <sup>ab</sup>	495 <sup>a</sup>	344 <sup>bc</sup>	331 <sup>bc</sup>	316 <sup>c</sup>	331 <sup>bc</sup>	35	< 0.01
Total deposition	775	772	716	694	691	712	34	0.10
Fasting heat production	775	752	816	788	828	780	26	0.28

# Effect of guanidinoacetic acid on nitrogen utilization efficiency in pigs



Test treatment	Normal protein diet	Low protein diet	Low protein diet	Low protein diet
GAA content, mg/kg	0	0	300	1200
Intake, g/d	342	297	289	301
Fecal excretion, g/d	33	34	30	39
<b>Nitrogen digestibility %</b>	<b>90.7</b>	<b>89.0</b>	<b>89.0</b>	<b>88.0</b>
Urinal excretion, g/d	49	64	54	31
Deposition, g/d	260	200	205	231
<b>Digestible nitrogen deposition ratio %</b>	<b>84.1</b>	<b>75.7</b>	<b>79.2</b>	<b>88.2</b>

# Conclusion



- **There is big potential for improving the efficiency of protein utilization in pig feed.**
- **Costs should be put into consideration when improving feed protein digestibility.**
- **Theoretical support is needed in research to improve pig feed protein utilization.**

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