KANSAS STATE UNIVERSITY | Biological and Agricultural Engineering

Incorporation of sweet sorghum Juice in the current dry-grind ethanol process for improved ethanol yields, energy saving, and water efficiency

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Recife, Brazil.

CENTER FOR SUSTAINABLE ENERGY
KANSAS STATE UNIVERSITY

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Introduction

Ethanol production in the US

Production, availability, and use of fuel ethanol is expected to increase.

- Energy Independence and Security Act of 2007

- Varieties of Ethanol blended fuel exists in the US

❑Varieties of Ethanol blended fuel exists in the US

U.S. ETHANOL PRODUCTION CAPACITY BY STATE

PRODUCTION FACILITIES

(Million Gallons/ Year)

	Nameplate	Operating	Under Construction/ Expansion	Total	Installed Ethanol Biorefineries	Operating Ethanol Biorefineries	Refineries Under Constr./ Expansion
Iowa	3,963	3,958	52	4,015	42	41	3
Nebraska	1,992	1,897	-	1,992	26	23	-
Illinois	1,421	1,384	-	1,421	15	14	-
Indiana	1,148	936	-	1,148	14	12	-
Minnesota	1,147	1,129	-	1,147	22	21	-
South Dakota	1,019	1,019	-	1,019	15	15	-
Ohio	528	528	-	528	7	7	-
Wisconsin	506	506	5	511	9	9	1
Kansas	504	479	45	549	12	11	2
North Dakota	360	360	65	425	4	4	1
Texas	355	205	-	355	4	2	-
Missouri	271	256	-	271	6	6	-
Michigan	268	268	-	268	5	5	-
Tennessee	225	225	-	225	2	2	-
California	223	178	-	223	6	4	-
New York	164	164	-	164	2	2	-
Oregon	149	41	-	149	3	2	-
Colorado	125	125	-	125	4	4	-
Pennsylvania	110	110	-	110	1	1	-
Georgia	101	101	-	101	2	2	-
Virginia	65	-	-	65	1	-	
Arizona	55	-	-	55	1	-	-
Mississippi	54	-	-	54	1	-	-
Idaho	50	50	-	50	1	1	-
Kentucky	36	36	-	36	2	2	-
New Mexico	30	-	-	30	1	-	-
Wyoming	10	10	-	10	1	1	-
Louisiana	2	2	-	2	1	1	-
TOTAL U.S.	14,880	13,966	167	15,047	210	192	7

Source: Renewable Fuels Association, January 2014

13.3 Billion gallons

Source: U.S. Department of Energy/Energy Information Administration and RFA

**Estimated*

Sweet Sorghum

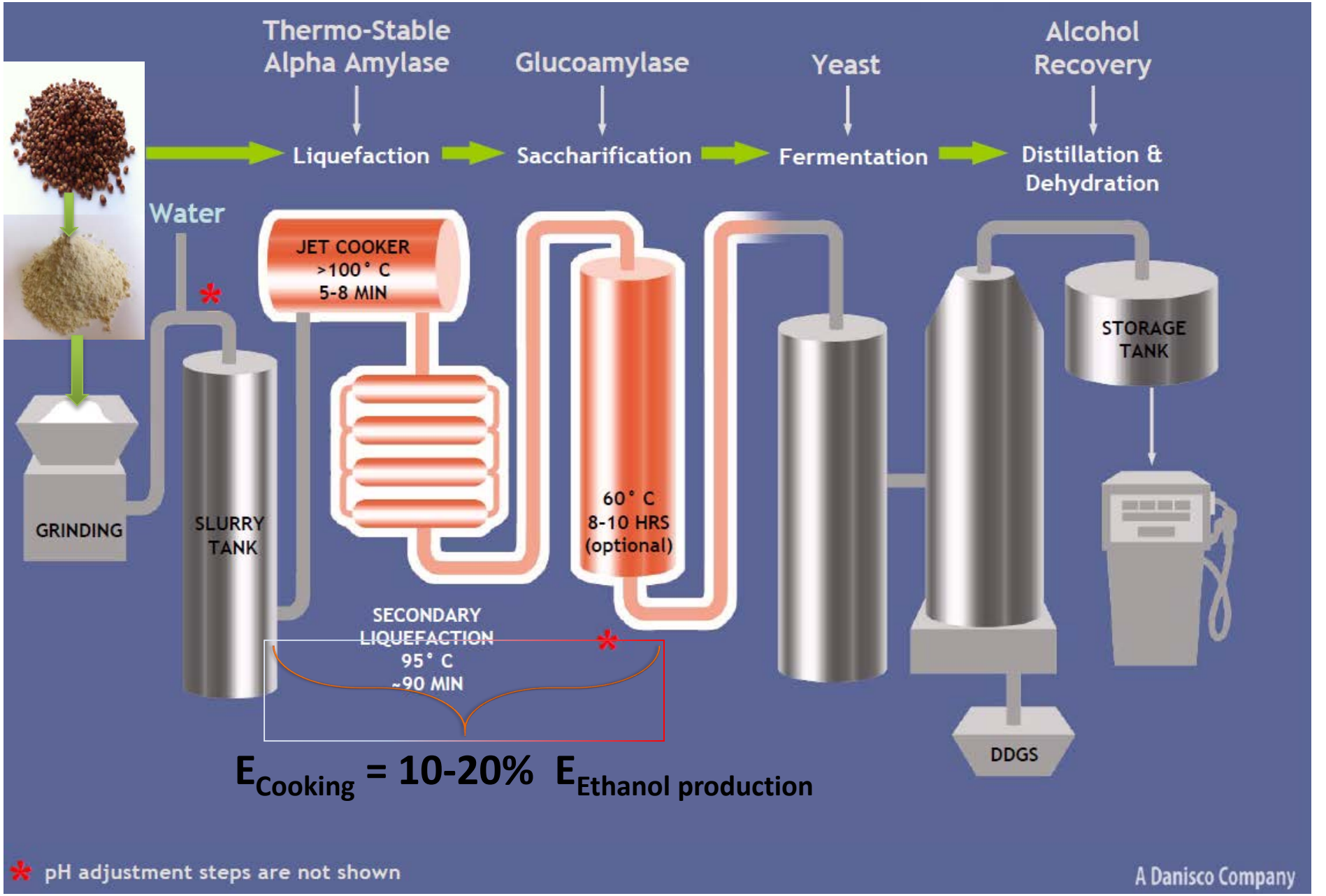
- Stem juice is rich in fermentable sugar - 53-85% sucrose, 9-33% glucose, and 6-21% fructose).
- Short period of growth period (140 days)
- Draught resistant.
- Higher biomass yield (45-80 t/ha).
- Environmentally friendly;
  - Requires less fertilizer, water usage for cultivation.

Objective

To develop a new technology for the current ethanol industry using sweet sorghum juice for ethanol production -

- to improve ethanol yield;
- safe water;
- energy conservation.

Conventional Dry – Grind Ethanol Production Process from Grain Sorghum



Methodology

Three phases

1. **Varying sorghum grain flour loading**

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2. **Varying enzymatic hydrolyzing time**

Three phases

1. **Varying sorghum grain flour loading**

2. **Varying enzymatic hydrolyzing time**

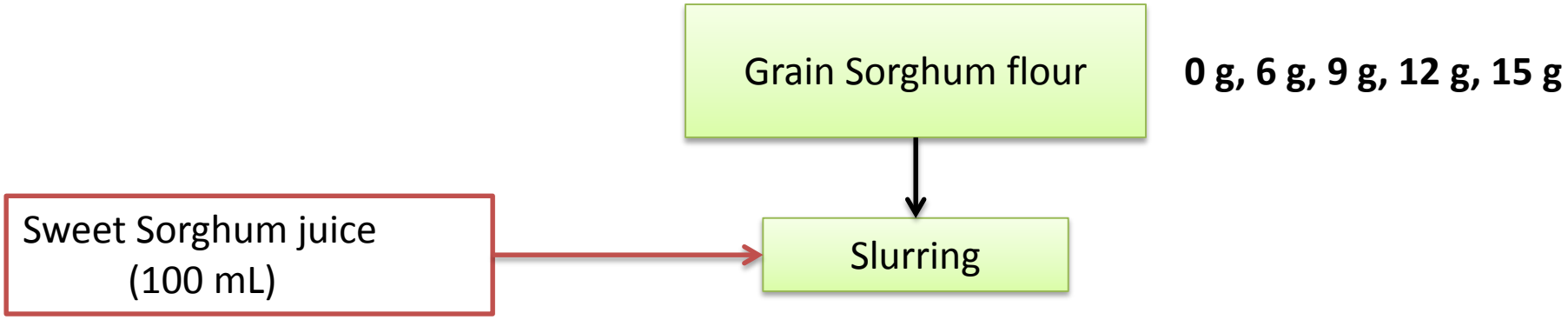
3. **Raw starch hydrolysis** (by GSHE)

(An <u>energy conserving</u> alternative process)

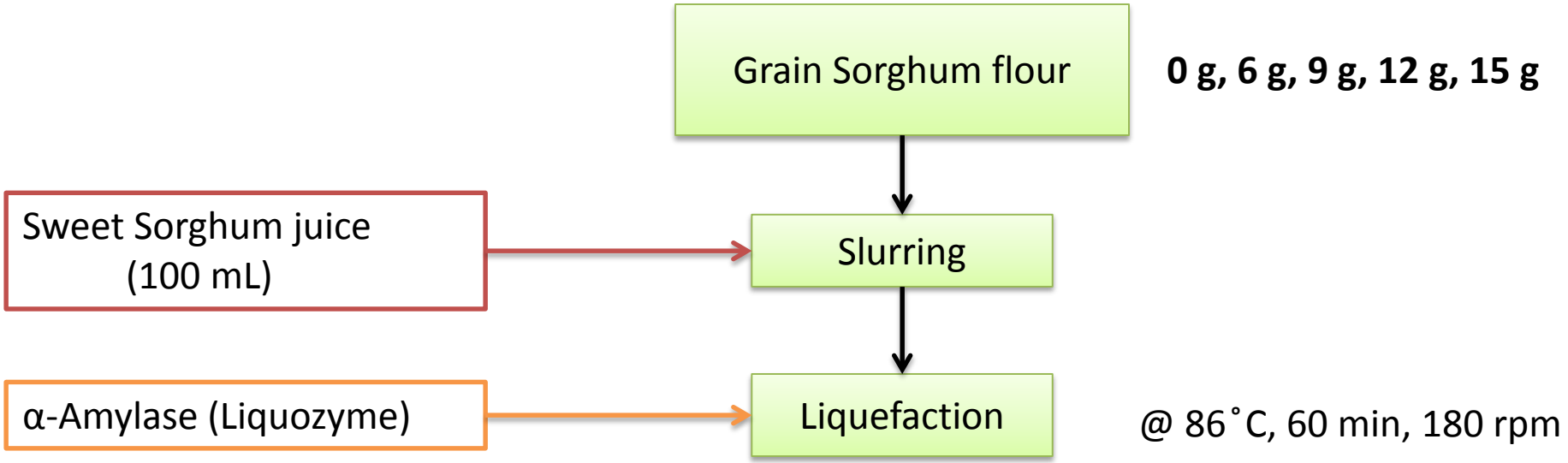
Ethanol Fermentation of sweet sorghum with varying sorghum grain flour loading

Grain Sorghum flour	**0 g, 6 g, 9 g, 12 g, 15 g**

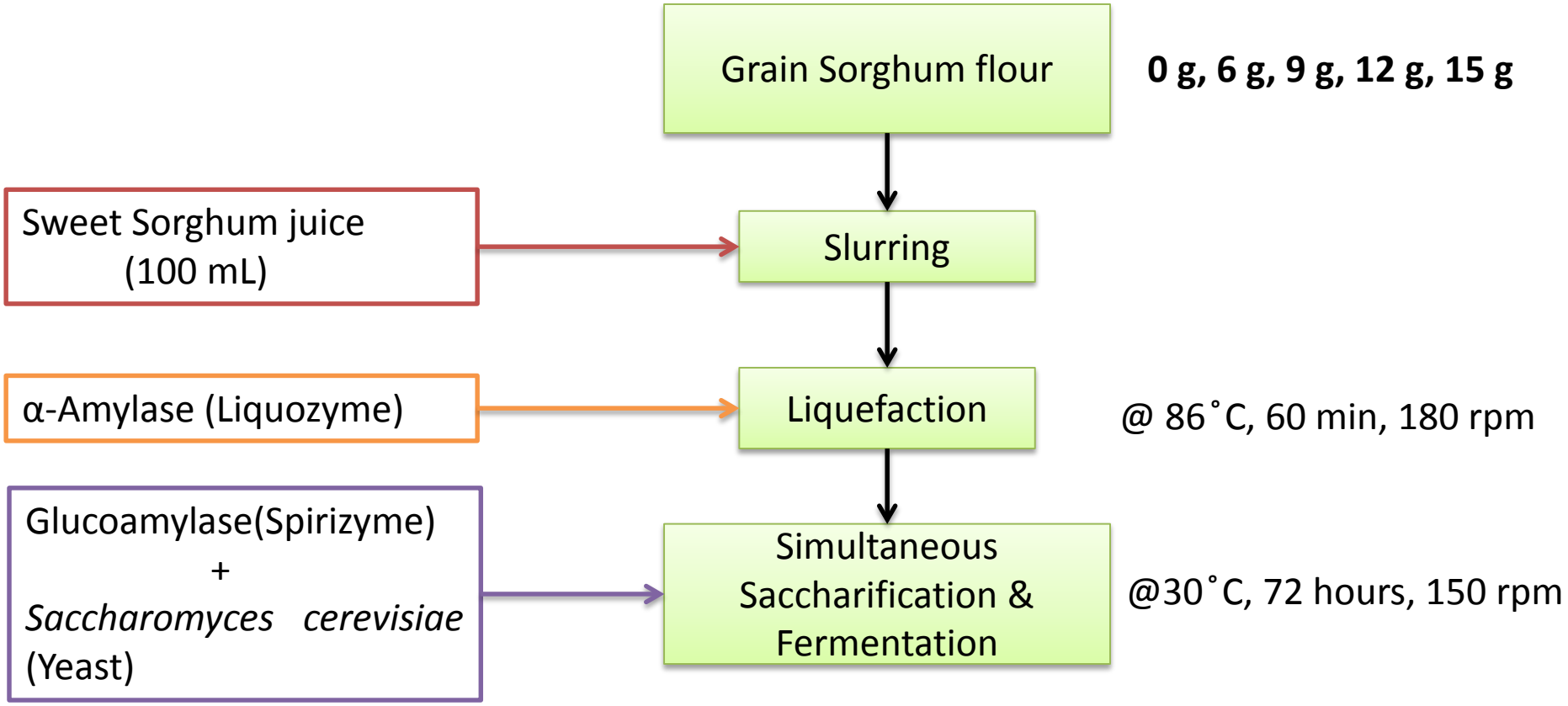
Ethanol Fermentation of sweet sorghum with varying sorghum grain flour loading



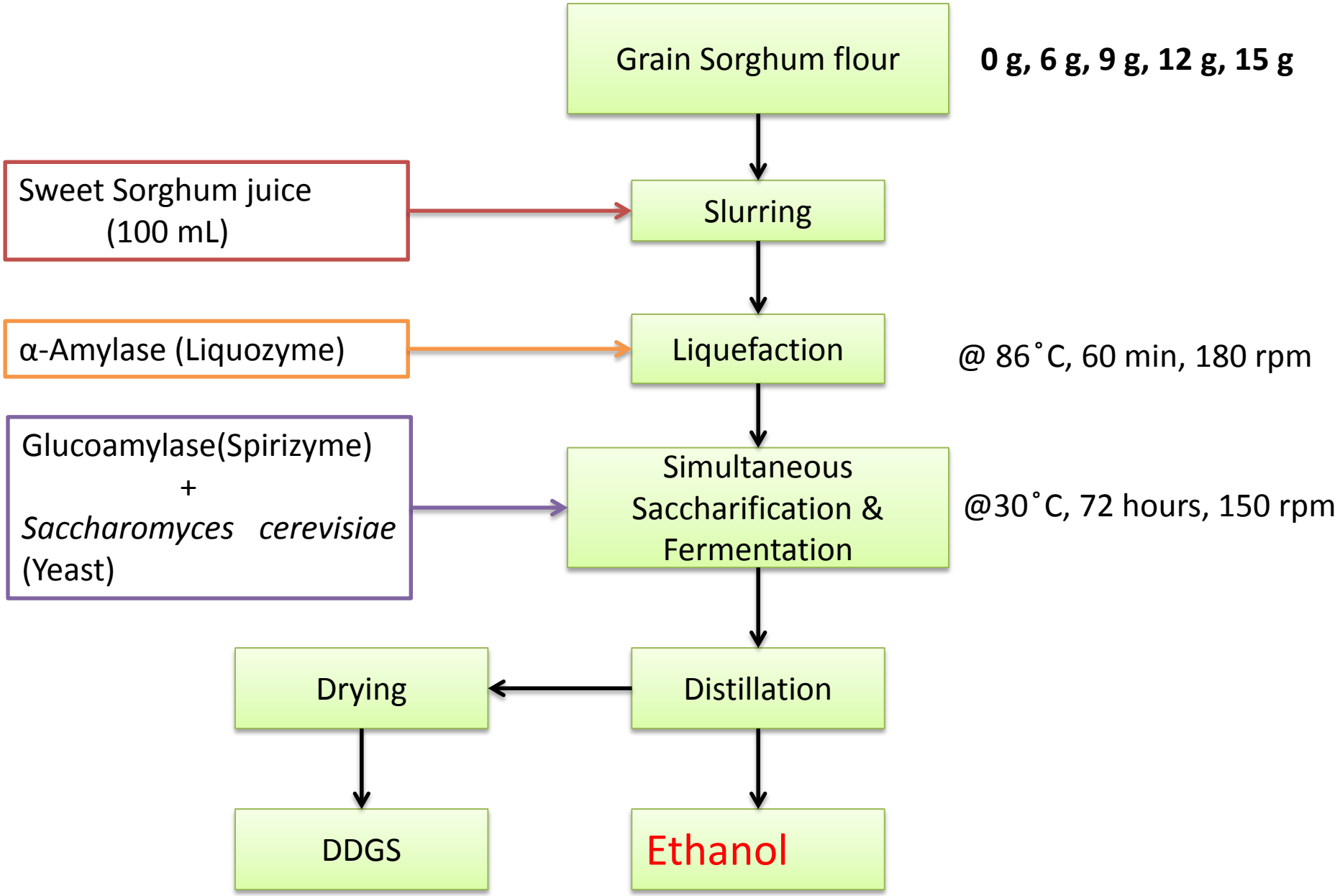
Ethanol Fermentation of sweet sorghum with varying sorghum grain flour loading



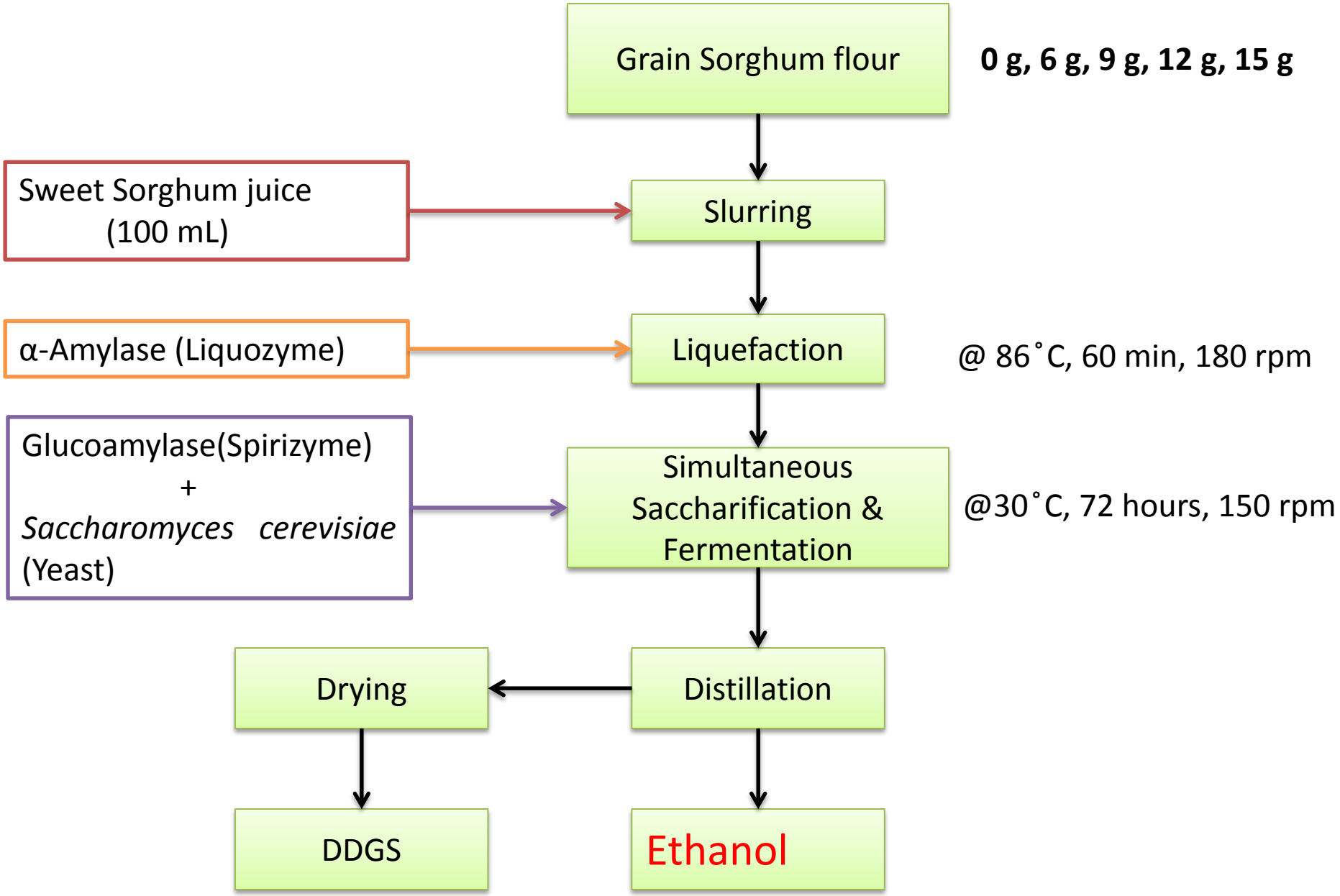
Ethanol Fermentation of sweet sorghum with varying sorghum grain flour loading



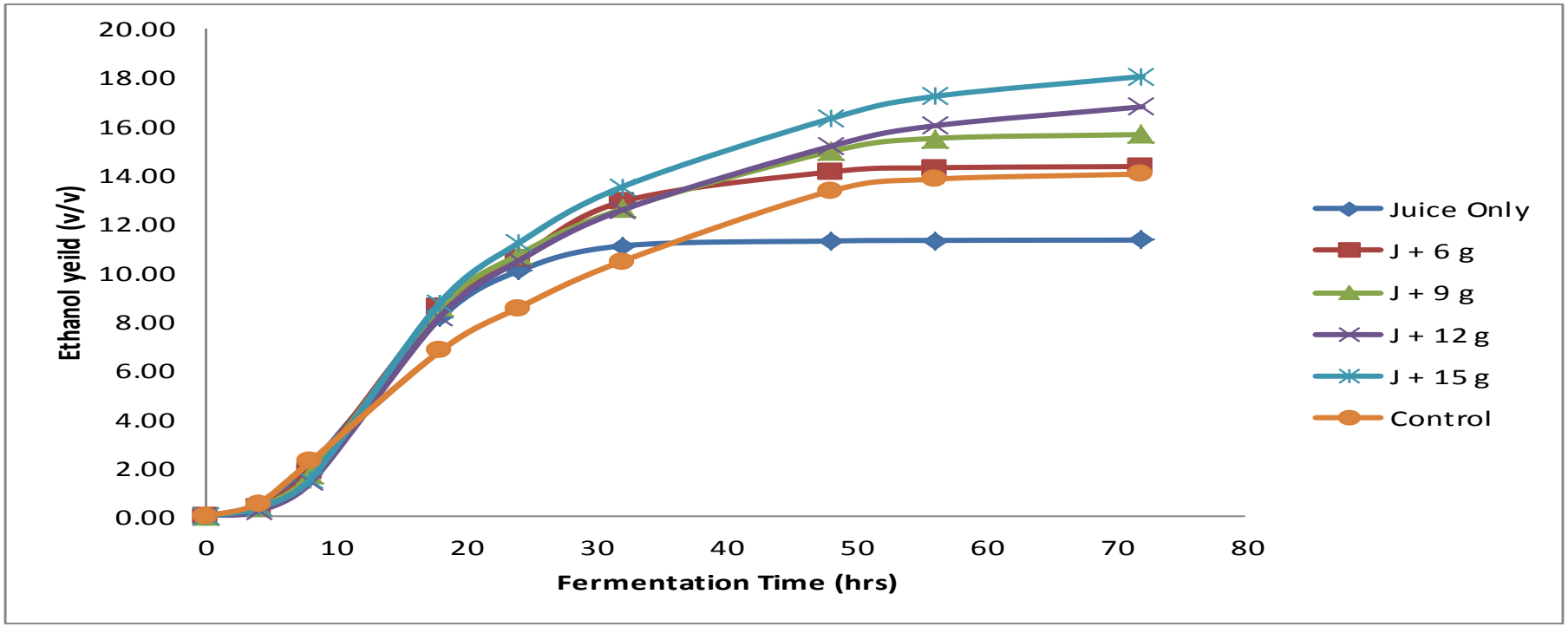
Ethanol Fermentation of sweet sorghum with varying sorghum grain flour loading



Ethanol Fermentation of sweet sorghum with varying sorghum grain flour loading



Results

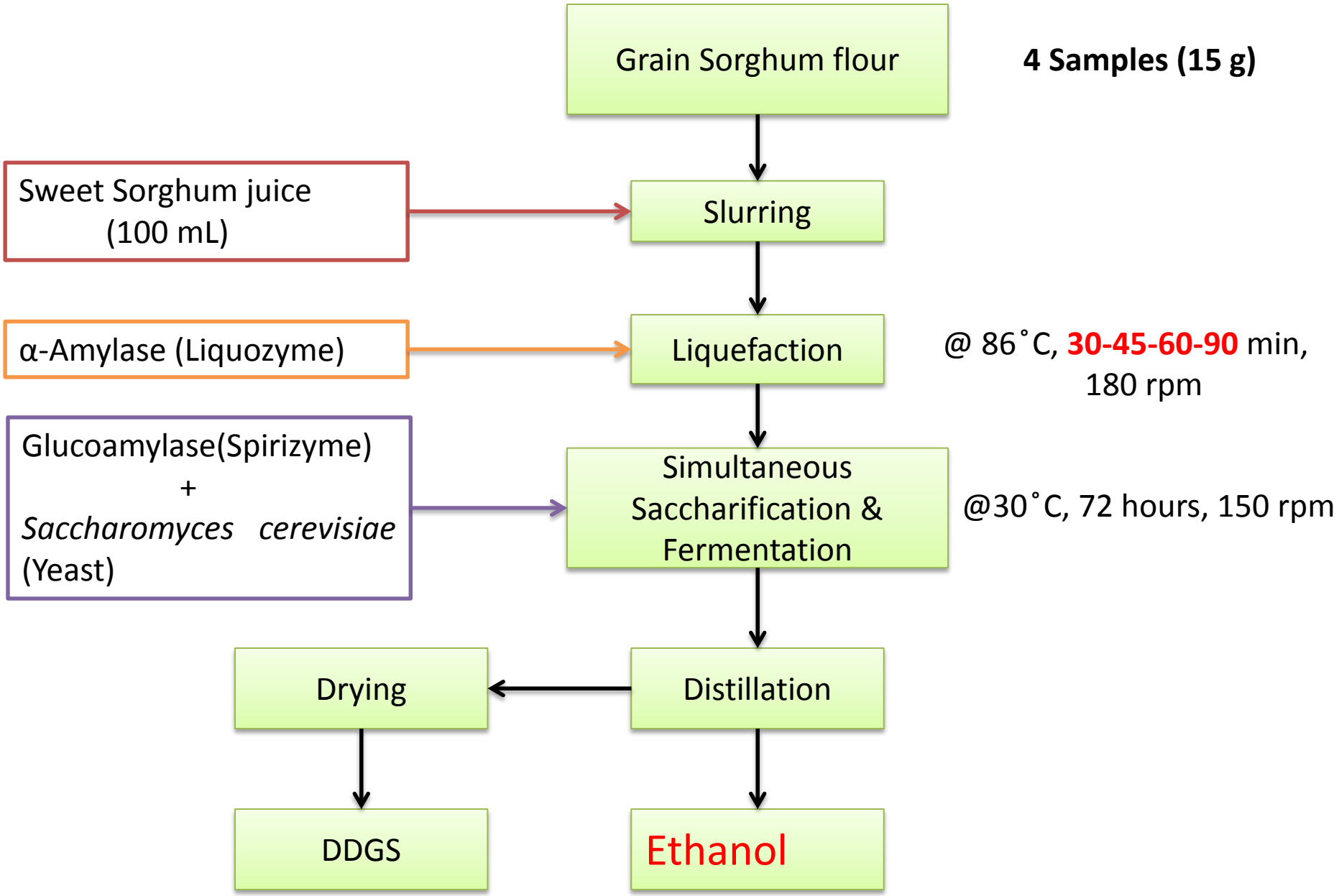


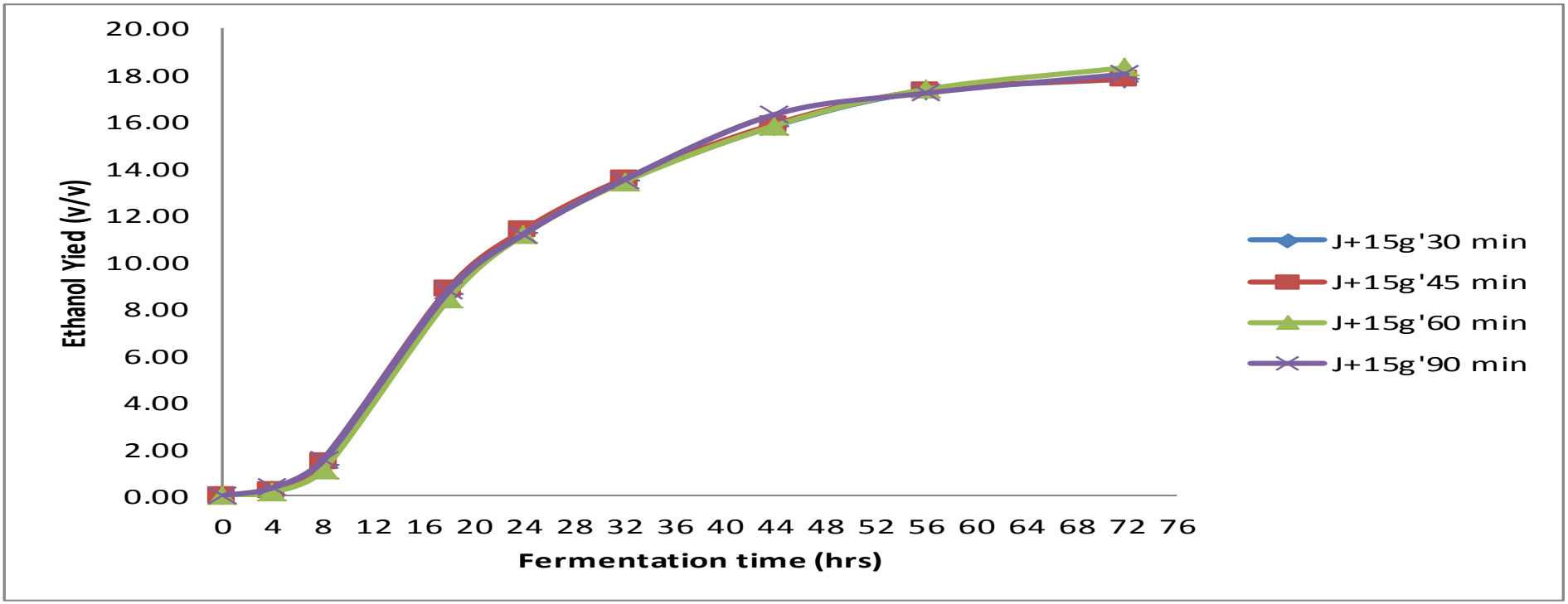
	Juice sugar content (%)	Flour starch content (%)	Theoretical ethanol yield (V/V)	Actual Ethanol yield (V/V)	Ethanol fermentation efficiency (%)
Juice only	18.89	0	12.12	11.29^{a}	93.15^{b}
Juice + 6 g flour	18.89	71.57	15.21	14.36^{b}	94.41^{a}
Juice + 9 g flour	18.89	71.57	16.75	15.67^{c}	93.55^{b}
Juice+ 12 g four	18.89	71.57	18.29	16.81^{d}	91.91^{c}
Juice + 15 g flour	18.89	71.57	19.95	18.05^{e}	90.48^{d}
Control- 30 g flour (db)	0	71.70	15.48	14.05^{b}	90.75^{d}

28.5 %

Means in the same column followed by different superscript letters indicate significant differences ($P \leqslant 0.05$).

Ethanol Fermentation of sweet sorghum with varying hydrolyzing time



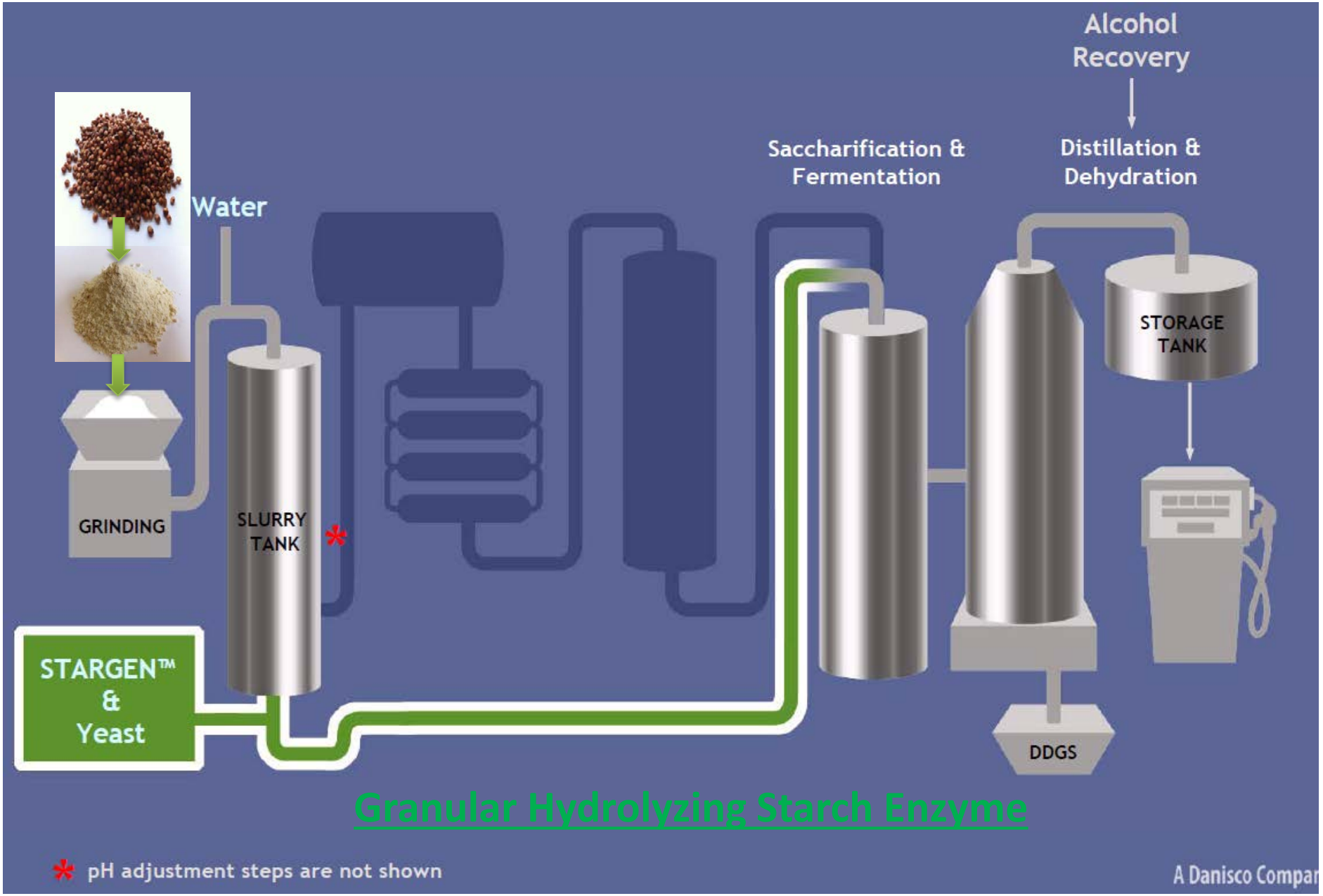


Hydrolysis time (min)	Juice sugar content (%)	Flour starch content (%)	Theoretical ethanol yield (V/V)	Actual Ethanol yield (V/V)	Ethanol fermentation efficiency (%)
30	18.89	71.57	19.95	17.84^{a}	89.42^{c}
45	18.89	71.57	19.95	17.85^{a}	89.47^{c}
60	18.89	71.57	19.95	18.33^{a}	91.88^{a}
90	18.89	71.57	19.95	18.05^{a}	90.48^{b}

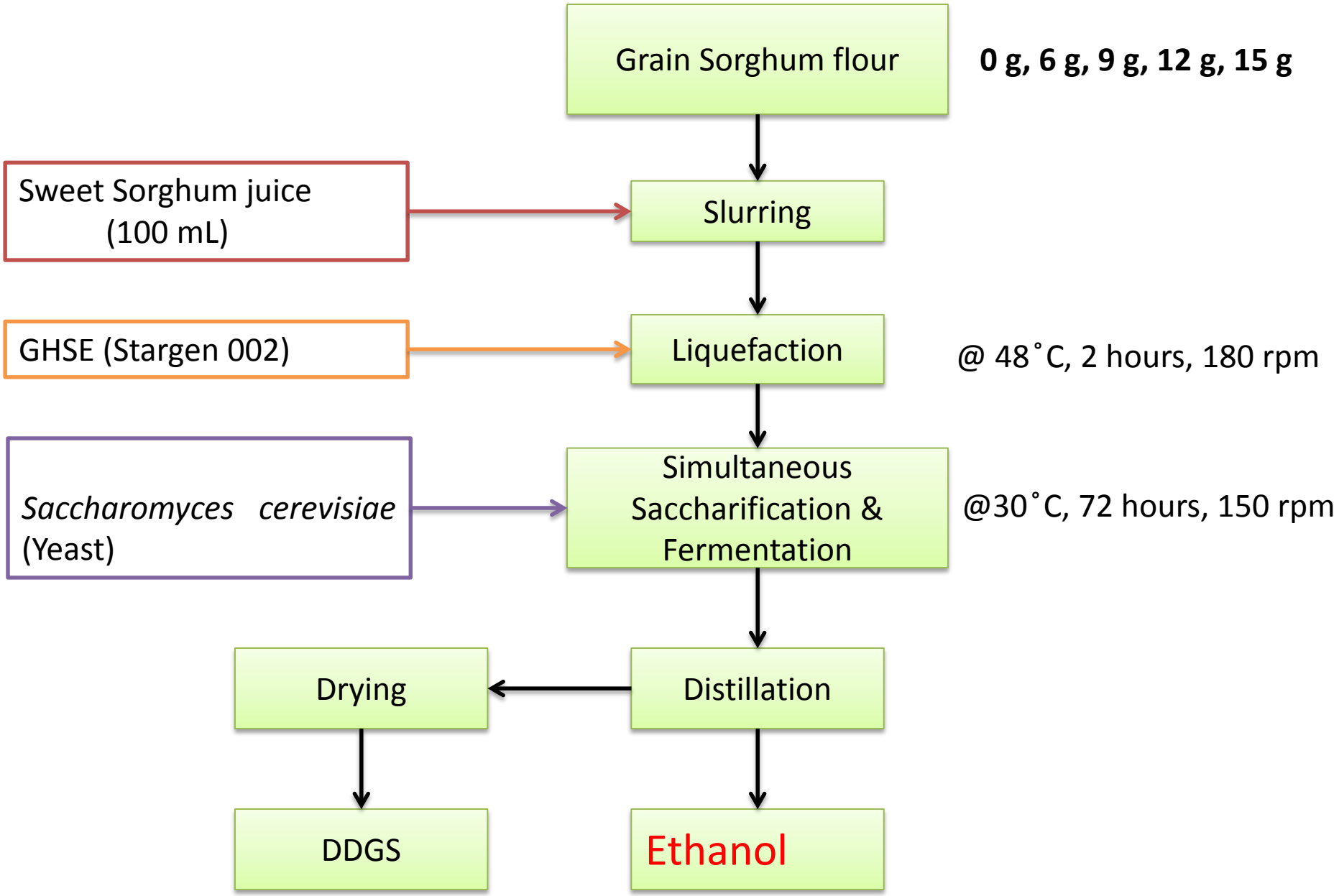
Means in the same column followed by different superscript letters indicate significant differences ($P \leq 0.05$).

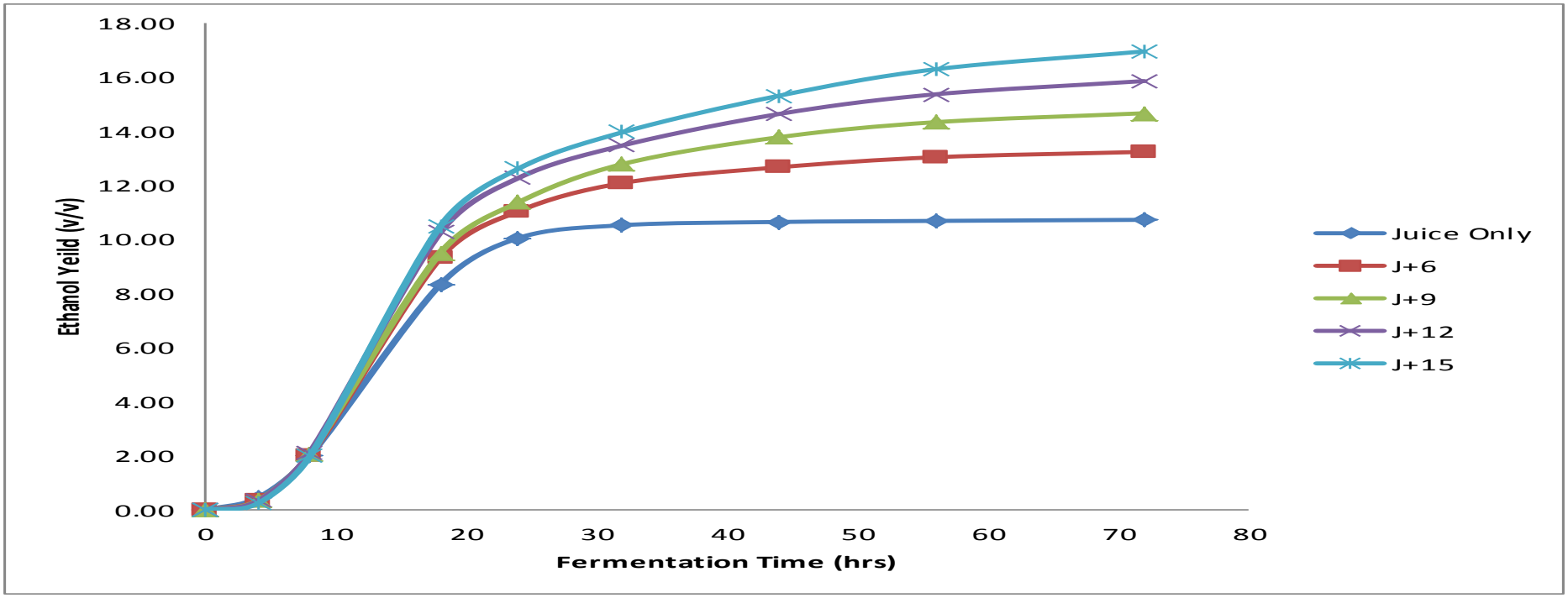
Low temperature hydrolysis

Low Energy Ethanol Production Process



Ethanol Fermentation by Granular Starch Hydrolyzing Enzyme (No Cooking)





	Juice sugar content (%)	Flour starch content (%)	Theoretical ethanol yield (V/V)	Actual Ethanol yield (V/V)	Ethanol fermentation efficiency (%)
Juice only	17.5	0	11.33	10.73^{a}	94.65^{a}
Juice + 6 g flour	17.5	71.57	14.42	13.24^{b}	91.82^{b}
Juice + 9 g flour	17.5	71.57	15.96	14.67^{c}	91.92^{b}
Juice + 12 g flour	17.5	71.57	17.51	15.87^{d}	90.63^{c}
Juice + 15 g flour	17.5	71.57	19.05	16.70^{e}	87.66^{d}

Means in the same column followed by different superscript letters indicate significant differences ($P \leq 0.05$).

Conclusion

- Ethanol yield : 28% higher than conventional ethanol method.
- Enzymatic hydrolysis time reduced by 30 minutes.
- Strong potential for ethanol production from by granular starch hydrolyzing enzyme.

Acknowledgment

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Thank You!